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BY

ROBERT W. HUTCHINSON, M.Sc.

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ROBERT W. HUTCHINSON, M.Sc.

AUTHOR OF "ADVANCED TEXTBOOK OF ELECTRICITY AND MAGNETISM," "INTERMEDI
TEXTBOOK OF ELECTRICITY AND MAGNETISM," "JUNIOR TECHNICAL ELECTRICITY
"A FIRST COURSE IN EXPERIMENTAL SCIENCE FOR TECHNICAL STUDENTS"
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PREFACE.

THIS book forms a companion volume to my *Easy Les in Wireless*, which has proved so successful.

As in the case of that book it is written essentially beginners and aims at giving a clear insight into the fur mentals and practical working of television by wireless witb assuming any knowledge of mathematics, electricity, opt radio-communication, or television. The non-technical rea can therefore truly " begin at the beginning " of the subj Its language is simple, technical terms are reduced tc minimum, and where their introduction is necessary they in all cases explained in a way which is really understanda to the " man in the street." Nevertheless, the book aims basing the knowledge the reader acquires on sound scient principles. Modern views are introduced from the outs and the whole of the scientific principles are correctly de with: it will not be necessary for the reader to discard th at a later stage in his studies.

My point of view is that of one who has had many ye teaching experience with students of all ages in Day Schoo Technical Institutes, and University Classes, close associati with Wireless Societies, and over twenty years' experien with experimental radio work. This will explain why certa portions are treated at comparatively great length and certa portions particularly emphasised and even repeated. Tl experience has also shown me that the conception of potenti the visualisation of the electronic current, etc., the " twistir round " of old ideas to fit the new, can be appreciated even l young beginners if the matters are dealt with in a homel

There is no doubt that television has a wonderful future, and in addition to the large number of students who are deeply interested, there are thousands of people with little or no scientific training who are anxious to know something about it: this book endeavours to explain in simple language how it is done. Of the many systems proposed, the Baird system—solidly "British"—has proved superior to all, and that system is the one particularly dealt with. Apart from the vision aspect of the subject, details are given of the wireless receiver portion of the receiving apparatus, and circuits described which have proved successful on the recent television broadcasts. Sections are also devoted to tele-cinematography, tele-talkies, television in the theatre, and tele-photography.

My thanks are due to various manufacturing firms, mentioned in the text, who have kindly supplied blocks where required. My best thanks are also due to Mr. H. J. Barton Chapple, B.Sc., A.M.I.E.E., of *Television* and the *Television Press* for the very kind loan of the photographic illustrations. The illustration on the cover of the book is reproduced by kind permission of the British Broadcasting Corporation.

R. W. HUTCHINSON.

CAMBRIDGE, OCTOBER 1930.

CONTENTS.

CHAPTER I.

A FEW NECESSARY IDEAS ABOUT ELECTRICITY.

1. The Tiny Atom and the Very, Very Tiny Electron.—The name *substance* or *material* or **matter** is perpetually used in every-day life by almost the youngest and the oldest of us, but it is not altogether easy to explain exactly what "matter" is. The scientist certainly gives us a definition; he may tell us that matter is "that which occupies space," but this seems rather vague to a beginner. For our purpose, however, we will take it that, in simple, homely language, matter is all the different kinds of stuffs that we can see, feel, weigh, etc. Some are solids, such as copper; some are liquids, such as water; and some are gases, such as air. Gases cannot be seen or felt, but we can weigh them and sometimes smell them and sometimes turn them into liquids or solids.

Now in order to understand many facts in modern science —indeed to understand such modern every-day conveniences as the electric light, electric trains and trams, telegraphy, telephony, wireless, and television—it is necessary to have some idea as to how matter is made up, and in order to drive the idea home to the reader with little or no scientific training or knowledge we must do a little "imagining." Professor Clark-Maxwell used to imagine a tiny being, a "little demon" with the same faculties as ourselves (but considerably sharper) who was able to see things infinitely smaller than we can see, and do things infinitely smaller than we can do. We will adopt a somewhat similar plan.

We know from ordinary experience that every piece of matter can be divided into smaller pieces by suitable means. We can split up a large sheet of glass into very tiny pieces, and we can go on pounding the tiny pieces until we get a fine glass powder. If we drop a crystal of permanganate of potash

consists of one revolving negative electron outside the nucleus and a nucleus consisting of a proton with an equal free positive charge, an atom of helium has two electrons outside the nucleus, and the latter consists of two equal free positive charges, lithium has three electrons and a nucleus with three equal positive charges, beryllium has four, boron five, carbon six, nitrogen seven, oxygen eight, and so on up to uranium with ninety-two.

But the marvellous thing to bear in mind just now is that when we get to rock-bottom, the atoms of all these elements merely consist of a nucleus of positive electricity (protons), and a number of rapidly moving particles of negative electricity or electrons. Of course, most of the substances we encounter in daily life—our own bodies, our buildings, the "things" we come across every day—are not elements and are not listed in the chemist's periodic table: they are, however, built up of various elements, so that when we get down to the fundamentals of all materials we have the protons and very tiny electrons as indicated above.

And it is this structure within the atom which endows matter with all its electrical and chemical properties; it is due to these electrons that we have such modern conveniences as electric light, electric trains, telegraphy, wireless, television, and so on.

2. Positive and Negative Charges of Electricity.—The ancients knew that pieces of amber possessed, when rubbed, the property of attracting light bodies, and it is from the Greek name **ëlektron** (amber) that our word "electricity" is derived.

It is now well-known that, with proper precautions, all substances, suitably rubbed, will attract to some extent such light articles as pieces of paper, bran, cork, pith, etc.: glass rubbed with silk, sealing-wax with flannel, and vulcanite with fur, do so in a marked degree. A substance endowed with this property is said *to be electrified*, *to be excited*, *to be charged*, *to possess a charge*, or *to be in a state of electrification*, and the agent which is the cause of this state is named **electricity**.

Now if you rub a vulcanite rod with fur and suspend it by a dry silk thread from a suitable stand and then bring near it another vulcanite rod which has also been rubbed with fur, the suspended one will be repelled: but if you bring near it a glass rod which has been rubbed with silk the suspended rod will be attracted. Similarly if the electrified glass be suspended, a second glass rod excited with silk will repel it, but the vulcanite rod rubbed with fur will produce attraction.

Numerous early experiments like the above with various substances led to the conclusions (1) that there were two states of electrification, (2) that bodies in similar states of electrification repelled each other, (3) that bodies in unlike states of electrification attracted each other.

It was agreed in those early days to call the state of electrification of glass rubbed with silk, **positive,** and to say that the glass was "*positively*" *charged*; it was further agreed to name the state of electrification of vulcanite rubbed with fur **negative,** and to say that the vulcanite was "*negatively*" *charged*. Hence we have the important laws: (1) Positively charged bodies repel each other. (2) Negatively charged bodies repel each other. (3) A positively charged body and a negatively charged one attract each other.

So far we have not bothered about the rubber, but it can be shown that when vulcanite is rubbed with fur, not only is the vulcanite negatively charged, but at the same time the fur is positively charged and by an equal amount. Similarly with the glass—the glass is positively charged and the silk is, at the same time, negatively charged and by an equal amount.

Now let us get back to our atoms—our protons and electrons—and see if we can get an explanation of the preceding. Remember this: If we remove electrons from the atoms of a substance we may change the properties of the substance altogether and produce what is known to us as quite a different substance. On the other hand, the removal of electrons (or the addition of electrons) may simply produce electrification. The latter is the case which concerns us at present.

case the attractions and repulsions between the atoms balance, *i.e.* the atoms as a whole neither attract nor repel each other: they are neutral.

In Fig. 2 one of the electrons has been detached from one atom and absorbed by the other, so that the first atom is positively charged, since the positive nucleus predominates, and the second atom is negatively charged, since the negative electrons predominate. The positive portion of the first atom tries to recapture the electron it has lost and to which it is entitled (or to get hold of another one in place of it), and the electron is equally anxious to get back: thus the attraction between the two oppositely charged atoms is due to the attraction between the extra positive nucleus charge in one and the surplus electron in the other.

An atom which has lost an electron is usually spoken of as a **positive ion**, and one which has gained an electron as a **negative ion**. The force between a positive ion and an electron is enormous, almost beyond our comprehension: if gravity were as great, a man would weigh hundreds of tons.

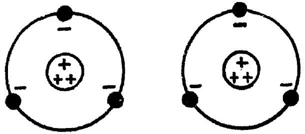


Fig. 1.
Neutral Atom. Neutral Atom.

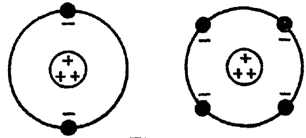


Fig. 2
Positive Atom. Negative Atom.

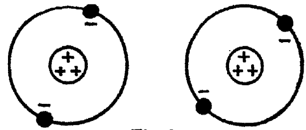


Fig. 3.
Positive Atom. Positive Atom.

In Fig. 3 we have two atoms which have each lost an electron, so that both are positively charged. In this case the repulsions between the atoms overbalance the attractions, and the result is repulsion. A similar result follows in the

case of two atoms which contain an extra electron each, and are, therefore, negatively charged.

When vulcanite is rubbed with fur some electrons are detached from the fur atoms and transferred to the vulcanite atoms. The vulcanite has a surplus of (negative) electrons, and is negatively charged: the fur has a deficit of electrons so that the positive centres predominate and the fur is positively charged. When glass is rubbed with silk, electrons are transferred from the glass to the silk so that the glass is positively charged and the silk negatively charged.

We have seen that an electrified body attracts light bodies and attracts or repels other electrified bodies. Now the space surrounding an electrified body within which the influence of the electrified body extends is called an **electric field.** If a small positive charge absolutely free to move were placed at any point in such a field, it would be urged by a definite force in a definite direction and that direction can be indicated by what is called a **line of electric force** passing through the point in question.

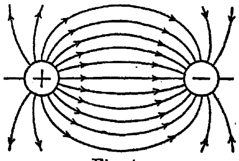


Fig. 4.

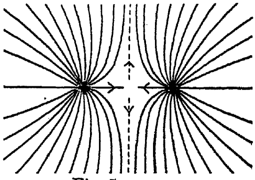


Fig. 5.

Fig. 4 shows the lines of electric force in the case of two metal balls with equal charges, the one positive and the other negative, and Fig. 5 shows the lines in the case of two equal positive charges placed at points a short distance apart. It should be noticed that in the latter case the lines from the two like charges turn away from each other, but in the former case the lines pass from one body to the other.

In order to explain attraction between unlike charges and repulsion between like charges Faraday imagined these line of electric force to be, so to speak, real connections between

the charges, and further he imagined that each line tended to shorten in the direction of its length, whilst lines proceeding in the same direction tended to repel each other laterally, *i.e.* sideways.

Clearly this contraction in the direction of their length will account for the attraction between unlike charges (examine Fig. 4) for this will tend to pull them together, and repulsion sideways will give an explanation of the repulsion between like charges (examine Fig. 5) for this will tend to move them apart.

Suppose you have a light pith ball suspended at the end of a silk thread and, holding the thread in the hand, you bring the pith ball gradually near a strongly electrified body: when you get to within a certain distance of the latter the pith ball is attracted towards it. Now hold a large sheet of metal—say copper—in between the pith ball and the charged body: the pith ball is no longer attracted. The sheet of copper, (which is really *joined to earth* by your hand and body) acts as a **screen** protecting or screening the pith ball from the influence of the electrified body. The lines of force from the charged body end, in fact, on the earth-connected plate and do not pass through into the space beyond. Metal plates are largely used in this way as screens in wireless receivers.

3. The Electric Current: Resistance.—In these days most people know that the expression "electric current" means a flow of electricity—frequently along a metal wire—and most people know something about a "battery," which is one of the many devices for producing an electric current.

The action of a battery, as will be seen later, is simply this; it causes an excess of electrons to be piled up at the negative pole of the battery, and at the positive pole of the battery an excess of positive ions, *i.e.* atoms which have lost an electron: further, what is termed a "difference in electrical pressure" is set up between the poles, and as soon as a road is made between these poles by joining them with, say, a copper wire, this difference in electrical pressure drives electricity along the wire. All this will be understood later.

Suppose then a copper wire with its end *A* joined to the positive pole of the battery and its end *B* joined to the negative

pole. To fix ideas we will do a little more "imagining." Imagine that, before the wire is joined up as above, you have once more become the "little demon" and that you are just up against the surface of the wire having a peep inside. You would, of course, see a large number of atoms each with its positive nucleus and its revolving electrons.

Now suppose someone joins up and "starts the current." You would immediately see a huge army of electrons—millions of them in fact—coming from the direction of B towards the direction of A, going in between the atoms and through the atoms, colliding with each other and with the electrons in the atoms, driving some of the latter out and taking their place.

This hurrying, scurrying, bumping movement of electrons in the general direction B to A of the copper wire, *i.e.* from the negative pole to the positive pole of the battery, is the **electric current**, and the greater the number of electrons passing per second the greater is said to be the **strength of the current.** We will call this the **electronic current** for a reason which will be seen presently.

Now let us get back to earth again and examine the process a little more in detail. Let us, for example, concentrate our attention on one of the free electrons at the negative pole of the battery. This electron rushes into an atom at the end B of the wire, and it does so with such force that it drives out one of the atom's own electrons and takes its place. This evicted electron dives into the next atom, driving out an electron and taking its place. And so this goes on from atom to atom all along the wire, until finally at A an evicted electron is taken in by a positive ion waiting, as it were, for it. As to what happens next, you need not trouble at present—that is the story of how a battery works.

Of course, in practice, it is not a matter of one electron entering the end B and another leaving the end A of the wire, but millions upon millions per second, and, of course, considerable bumping.

Again, all this knocking, this bumping, this wrenching-out of the electrons in the atoms, means that the current is encountering a certain difficulty in, a certain opposition to, its flow;

this is spoken of as the **resistance** of the electric circuit. Clearly *the less the resistance the greater will be the current strength.*

Now just as we measure distances in terms of a certain unit—the yard, the foot, etc., and mass in terms of a certain unit—the pound, the ounce, etc., so we measure current strength in terms of a certain unit of current strength, and resistance in terms of a certain unit of resistance. The unit of current strength is called the **ampere** and the unit of resistance is called the **ohm**. For the present, however, you should merely remember that we speak of *a current strength of so many amperes* and of *a resistance of so many ohms.*

4. Electric Potential or Electric Pressure.—One of the most important ideas in the study of electricity is what is known as **electrical potential** or **electrical pressure,** and it is essential that you should try to grasp the idea. It will help towards this end if you first consider the following analogies, bearing in mind, however, that though the analogies are helpful, they are rather faulty in detail and must not be pushed too far.

It is well known that heat flows from a body at a high temperature to a body at a low temperature. If two bodies be connected together by a conductor of heat, and no heat passes from one to the other, the two bodies are at the same temperature; if the two bodies are at different temperatures, then heat will flow from the one at the higher temperature to the one at the lower temperature, and this flow will continue until the two come to the same temperature.

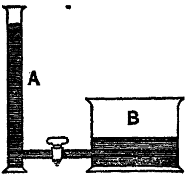


Fig. 6.

It is also well known that water flows from a high water level to a low water level. Thus, if the two vessels of Fig. 6 contain water as indicated, then on opening the stop-cock water will flow from **A** to **B,** and the flow will continue until the two come to the same level. The actual quantity of water in **B** may be considerably greater than the quantity in **A**; *it is the difference in level which settles the direction in which the water will flow.*

Again, consider an air-tight box fitted with a stop-cock and a pressure-gauge. Pump air into the box and then close the stop-cock. The gauge will indicate that the air pressure inside is greater than that outside. Open the stop-cock; *air will pass from the box into the atmosphere*, i.e. from the region of higher pressure to that of lower pressure, and this will continue until the gauge indicates that the air pressures inside and outside are the same. Now draw air out of the box, and then close the stop-cock. The gauge will indicate that the air pressure inside is less than that outside. Open the stop-cock; *air will then pass from the atmosphere into the box*, i.e. from the higher pressure to the lower pressure, and this will continue until the gauge indicates that the air pressures inside and outside are the same.

Again, in measuring temperatures by a Centigrade thermometer, the temperature of melting ice is taken as the standard of reference or the zero. Similarly, in measuring heights of mountains, etc., the sea-level is taken as the zero level.

In the study of electricity *electrical pressure* or *electrical potential* has much the same meaning as temperature, level, and pressure in the above cases. Now in the early days the pioneers in electricity did not know so much about the subject as we know now—they knew nothing about electrons and protons and the inside of an atom—and so the names they invented and the ideas they put forward to explain things are sometimes not altogether in harmony with recently discovered facts. The names, however, are still in use, and a certain amount of " twisting round " so to speak is necessary to make them fit in with modern ideas. This is rather confusing to a beginner, but the difficulty disappears later. One of these difficulties is cropping up now.

Consider a positively charged brass ball hanging by a silk thread. We know that this has got a deficit of electrons. Now if this ball be joined to the earth by a wire, we find it becomes neutral and we know the cause—electrons must have come up from the earth to make up the deficit, *i.e. an electronic current has passed from the earth to the ball.*

But the early pioneers did not know about these electrons, and they reasoned in this way. The positive ball, they said,

has a surplus of electricity: when joined to earth this surplus electricity flows to earth, and it does so because the electrical pressure (or potential) of the ball is higher than the electrical pressure (or potential) of the earth. *The electric current*, they said, *flowed from the higher potential ball to the lower potential earth.* Further, the earth was taken as the zero of potential, and the ball was said to be at a positive potential.

As this latter current is still frequently spoken of we call it the **conventional current** to distinguish it from the true electronic current which flows the other way.

Again, if a negatively charged ball, *i.e.* one with a surplus of electrons be joined to the earth it also becomes neutral, and we know that this must be due to the surplus electrons passing to earth, *i.e. an electronic current has passed from the ball to the earth.*

But the early pioneers said this: The negative ball has a deficit of electricity: when joined to earth electricity flows from the earth to make up the deficit, and it does so because the electrical pressure (or potential) of the ball is lower than the electrical pressure (or potential) of the earth. *The electric current*, they said, *flowed from the higher potential earth to the lower potential ball*, and as the earth is taken as zero potential, the ball was said to be at a negative potential: this current we must also call the conventional current to distinguish it from the true electronic current which flows the other way.

To summarise then we may say: The potential of a body is its electrical pressure above or below that of the earth which is taken as the standard or zero: it is the electrical condition which settles the direction in which an electric current will flow. *A body A is at a higher potential or electrical pressure than a body B if a conventional current tends to flow from A to B, and of course a true electronic current from B to A, and A and B are at the same potential if electricity does not tend to flow between them.*

Potential difference (P.D.) or electrical pressure difference is therefore necessary in order to get a flow of electricity, *i.e.* a current, and if we want to keep up the current we must keep up the potential difference.

The positive pole of a battery is at a higher potential than the negative pole, and when joined by a wire this potential difference or pressure difference drives a current through the wire. The current is really a movement of electrons—the electronic current—from the negative pole to the positive pole, but we still frequently speak of the current as flowing from the positive pole to the negative pole, *i.e.* we speak of the conventional current.

Electrical potential or pressure is measured in units called **volts**, *i.e.* we speak of *an electrical pressure of so many volts.* Clearly *the bigger the pressure or voltage between two points the bigger will be the strength of the current it drives between the two points.*

There is just another point which you must notice, and that is that when we electrify a body we do not *make* electricity. Further, dynamos are used in running factories, huge electric machines are used in power stations for heating and lighting and traction, magnetos are used on motor cars and motor cycles, batteries are used for electric bells, etc., but none of these generators, as they are called, *make* electricity: they no more manufacture electricity than a pump manufactures water. Electricity is in everything, all matter is really composed of it, and dynamos, batteries, etc., are merely pumps which give "head" or "pressure" to the electricity and make it able to do something it could not do before.

5. The Alternating Current.—The current from a battery is what is known as a **continuous current**; that is to say, so long as the external circuit is closed, the current flows continuously in one direction. There are, however, currents which do not flow in this way but regularly reverse, flowing for a certain time in one direction and then reversing, flowing for another period of time in the opposite direction; such are called **alternating currents.**

Referring to a simple analogy, we may say continuous currents correspond to the flow of water along a pipe fed by a force pump, while on the other hand alternating currents correspond to the flow of water along a pipe leading at one time from a force pump, and at another from a suction pump,

the water being alternately forced into the pipe and then sucked back again.

Now in order to grasp the idea let us again do a little imagining as we did in Arts. 1 and 3. Suppose you have a copper wire and that an alternating current, such as is sometimes produced by a machine in an alternating current power station for electric lighting, can be sent along the wire.

Imagine you are again the "little demon" and are up against the wire having a look inside. Imagine too that your idea of time in your new condition is altogether different, so that what is really a second of time in your normal condition now seems to be 2 minutes or 120 seconds in your new condition. Now let the alternating current be switched on.

You will see, just as you saw with the continuous current of Art. 3, an army of electrons tearing along, say towards your left, but the number of electrons flowing gets bigger and bigger until finally the increase in number stops. Then the number of electrons in the flow gets smaller (although the movement is still towards your left) and this decrease in number goes on until the flow to your left ceases.

Immediately, however, electrons begin to flow along in the opposite direction, *i.e.* towards your right. Once again the number of electrons tearing along gets bigger and bigger, until finally the increase in number stops. Then the number of electrons in the flow gets smaller (although the movement is still towards your right) and this decrease in number goes on until the flow to the right ceases altogether. Immediately, however, electrons start off again in the first direction—towards your left—and the action is repeated.

A complete surge in one direction, say to the left, is called an **oscillation**, and a double surge—to the left and back again to the right—is called a **vibration.**

Now if you had noticed the time which elapsed from the moment when you had a maximum number of electrons in the flow towards, say, the left, to the moment when you had a maximum in the next flow towards the left, you would find that it would be about two seconds of your new time, which is $\frac{2}{120} = \frac{1}{60}$ second of ordinary time. This $\frac{1}{60}$ second is called the *periodic time* or **period** of the alternating current and the

number of such time intervals in one second (60) is called the **frequency** of the alternating current.

Thus the frequency is 60 per second or, as it is frequently worded, the frequency is **60 cycles per second,** a cycle being the movement from, say, a maximum in one direction through zero to a maximum in the other direction and back again through zero to a maximum in the first direction.

We might represent this alternating current graphically by a curve such as is shown in Fig. 7. If the curve is above the line it means that the electrons are flowing in one direction—say to the left—and if the curve is below the line it means that they are flowing in the opposite direction—towards the right. The dots indicate the number of electrons in the flow (*i.e.* the strength of the current) although each dot must really mean millions of electrons.

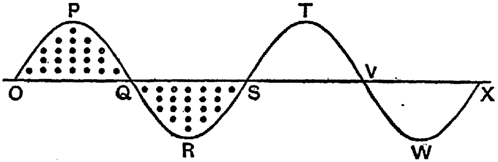


Fig. 7.

Thus the current strength increases from zero at **O** to a maximum at **P**, then decreases to zero at **Q**: then the current comes on in the opposite direction, and the strength increases to a maximum at **R**, then decreases to zero at **S**, and so on. The time taken from the condition **P** to the condition **T** (or from **O** to **S** or **Q** to **V**) is the *period*, and the number of these times in one second is the *frequency*.

The frequencies in common use are—for electric railways 25 per second, and for lighting and power 50 per second. Frequencies are spoken of as being "high" or "low," but you must remember that such terms are purely relative. Thus 100 cycles per second might be called a low frequency as compared with one of 10,000 cycles per second, which would be called a high frequency. When the frequency rises

to the order of 100,000 per second the current is generally called a **high frequency oscillatory current** or a " high frequency electric oscillation."

In wireless we really apply alternating current to the transmitting aerial in order that it may radiate energy which passes out into space in the form of waves—wireless waves—and for this to take place *very high frequency oscillatory current* is essential, as will be seen presently; in practice, this frequency used in wireless may be of the order one million cycles or more per second.

6. The Aether.—Now we must leave our electricity for a moment and consider very briefly a most extraordinary thin jelly-like stuff which is really everywhere—inside us, in our bones and flesh, everywhere outside us—although we cannot see it or feel it or smell it.

Scientists suppose that all space and all matter is filled with a medium called the **luminiferous aether** or simply the **aether.** This medium is invisible, odourless, practically weightless, elastic: it penetrates and fills all matter and all space: we move about in it but cannot feel it for it passes easily *through* our bones and flesh: the earth, the whole universe, is immersed in a limitless ocean of it. But the exact nature of it is a much discussed question.

We know that heat and light come to us from the sun and both travel millions of miles before they reach the atmosphere, and on this heat and light our very existence depends. We know also that heat and light come to us from the filaments of all electric lamps, yet many lamps are vacuum lamps, *i.e.* there is no air or gas inside—simply so-called empty space. Moreover, heat and light are both forms of energy, and in order to transfer energy from one place to another some medium is necessary: incidentally a medium conveying energy is always *strained* in doing so.

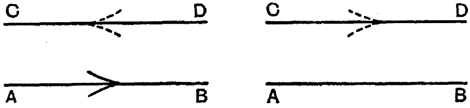
There must then be, in the space beyond our atmosphere and in the lamp vacuum some medium which can be strained. Further, many facts in science, which cannot be mentioned at this stage, demand that this same medium must exist in our atmosphere and in all forms of matter, as well as in the

so-called empty spaces referred to. This all-pervading medium is the aether.

If you stand at a distance and look at a forest it appears to be a fairly solid mass of timber, yet you know that the air, and even you yourself can get through between the trees all right. If then you think of an atom with its very, very tiny electrons a very, very big distance apart, and think of the aether as a very, very thin medium compared with air, you will understand how the aether can readily get through between the atoms and through the atoms themselves of what, to us, may be very solid bodies.

The importance of the aether from our present point of view, however, is that it is the medium which conveys to us the signals, the music, the songs, the speech, and the pictures in "wireless" and in "television": this will be understood later.

7. Agitations in the Aether: the Germ of all Radio Transmission.—Now we have talked about *continuous currents* in a wire, and *alternating currents*, and very high frequency alternating currents which we generally speak of as *high frequency electrical oscillations* or *high frequency oscillatory currents* (used in wireless), but in doing so we did not refer to the aether. We will now, however, have a word about it in connection with our currents.



Current starting in AB. Current stopping in AB.

Fig. 8.

Consider a wire **AB** (Fig. 8) and remember that the aether is *in* the wire and *in* the whole of the air outside the wire. Suppose we start a current in the wire in the direction **A** to **B**: electrons immediately begin fighting their way along the wire.

Now these millions of electrons suddenly starting off in this way *agitate the aether*—they give the aether, as it were,

a kick—and this agitation or disturbance spreads out *through the aether* in the air outside, just in the same way as the agitation which you create in a pond by moving a stick up and down spreads out along the surface in all directions. Bear in mind it is not the air which is agitated when the current starts, but the aether.

Further, if this aether disturbance comes across another wire **CD** even some distance from **AB** it agitates the electrons in **CD** and a current sets off in **CD** in the direction **D** to **C**, *i.e.* in the opposite direction to the current in **AB** which has caused the bother. The aether is only agitated by the current in **AB** when it just starts—when it is once started the aether is quite comfortable—and so the current in **CD** is only a momentary one. This current in **CD** is called an **induced current.**

Again, if the current in **AB** be stopped the aether is again agitated for a moment, and again for a moment a current is induced in **CD**, but this time in the direction **C** to **D**, *i.e.* in the same direction as the one which is stopping in **AB**. Similarly if the current in **AB** be suddenly increased or decreased in strength, then just at these moments the aether again receives a kick, the agitation spreads out, and again we have momentary currents induced in **CD**. Incidentally these disturbances travel out through the aether at a speed of 186,000 miles per second, the same as that of light.

It will be clear, too, that since an alternating current is constantly changing—increasing, then decreasing to zero, then increasing in the opposite direction, then decreasing to zero, and so on—if the current in **AB** is alternating the aether will be subject to repeated kicks and agitation, and currents will be induced in **CD** first in one direction then in the opposite direction, *i.e.* an alternating current will be induced in **CD**.

Now the above is really the germ of wireless. In the transmitting aerial (corresponding to **AB**) we really start up a high frequency oscillatory current: this agitates the aether and this disturbance travels out in the form of " aether waves " at a speed of 186,000 miles per second: these aether waves meet the receiving aerial (corresponding to **CD**) and start up oscillatory currents in it corresponding to those put on at the sending end. But all this will be explained later.

And you will see later how electric fields, such as we had in Art. 2, and others dealt with in the next chapter and called magnetic fields, are really connected with the aether disturbances referred to above.

Incidentally we might just draw your attention to another point about Fig. 8 before leaving it. In practice **AB** would be joined to a battery and would form part of a complete path or *closed circuit*—from the negative pole of the battery along **AB** to the positive pole and through the battery back to the negative pole again.

Similarly, to detect the current in **CD** its ends would be joined to some suitable current detecting instrument so that **CD** would also form part of a complete path or *closed circuit.*

Fig. 53 in fact rather shows what would be the actual arrangement of Fig. 8. All this is detail, however, and does not interfere with the general idea we have given you very simply by means of Fig. 8.

CHAPTER II.

A FEW NECESSARY IDEAS ABOUT LIGHT.

1. Light: Ray, Beam, Pencil.—Any textbook on the subject will tell you that "**light** is the external cause of the sensation we call *sight*," and as this definition is fairly simple and everyone is familiar with "light," we will leave it at that.

As a matter of fact, light really consists of an aether disturbance very much like the aether disturbance we dealt with in Art. 7 of Chapter I. Thus in Fig. 8 we saw that when a flow of electrons in **AB** was suddenly started or stopped or changed in any way, the aether was "agitated," the disturbance travelled out through the aether with a speed of 186,000 miles per second, and when it reached **CD** the electrons in **CD** were agitated in turn, and currents of electricity were developed in **CD**. Such aether disturbances as these do not affect any of our senses and so require special apparatus to detect them—such apparatus, for example, as is used in wireless.

Similarly in the case of a body "giving out light," *i.e.* a *self-luminous* body such as the sun or a red-hot piece of metal, the rapid movement of the electrons in the body gives rise to an aether disturbance, and this disturbance also travels through the aether at a speed of 186,000 miles per second. But Nature has given us a piece of apparatus which detects these particular disturbances—namely the eye: unlike the aether disturbances previously mentioned, when these disturbances meet the eye they give rise to the sensation we call "sight." All this, however, you will better understand later.

Anything which is itself "giving out light" is usually at a high temperature. The sun and stars are masses of glowing incandescent matter: a flame contains hot incandescent matter: the filament of an electric glow lamp is made hot and incandescent by the electric current passing through it: the cause of the light from an electric arc is mainly the very hot tips of the carbons.

All the above actually give out light and are called primary sources of light or **self-luminous** bodies. Other bodies—**non-luminous** bodies—in the presence of a self-luminous source, may become what we may call secondary sources of light by reflecting and scattering the light which falls on them from the primary source of light. Thus the moon and the planets are dark bodies and do not give out light themselves, but they reflect and scatter the light which falls on them from the sun and so become secondary sources of light. All the objects in a room in which there is a lamp or other primary source of light, or into which the sun shines, become secondary sources of light by reflecting and scattering the light that falls on them: it is owing to this scattering of the light that the objects in the room can be "seen."

Suppose you are in a dark room and that an electric glow lamp in the room is gradually heated by gradually increasing the strength of the current passing through it. As soon as the filament reaches a dull-red heat you will "see" it, *i.e.* the aether disturbance which the filament is causing is beginning to affect the eye and to excite the sensation of sight. As the temperature rises you will note that the filament glows more and more brightly until it reaches incandescence, and is seen as a brilliant white body. Meanwhile the objects in the room have been becoming more and more visible, not by giving out light themselves, but by reflecting and scattering from their surfaces more and more light falling on them from the lamp. We will have more to say presently about this reflecting and scattering of light by bodies which do not themselves give out light.

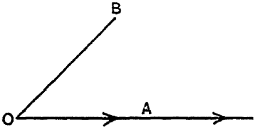


Fig. 9.

When light is sent out from a luminous body at **O** (Fig. 9) the disturbance which reaches any point **A** travels along the straight line **OA**, and the disturbance which reaches any point **B** travels along the straight line **OB**. This is what is meant by saying that "light travels in straight lines." Strictly this is only true if the space between **O** and **A** or **O**

and **B** is quite uniform throughout, *i.e.* is what we call a "homogeneous medium": if light passes, say, from air into glass it travels in a straight line in the air and in a straight line in the glass, but the line is bent at the surface separating the glass and air (Fig. 14). This bending of light at the surface separating two media when the light passes from one medium into the other is what we call the refraction of light.

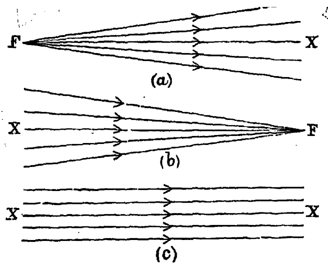


Fig. 10.

The disturbance travelling along the straight line **OA** is called a **ray** of light, whilst a collection of rays is called a **beam** of light. If the various rays of a beam spread out or diverge from a point **F** (Fig. 10, *a*) it is called a *diverging beam*: if they go towards or converge to a point **F** (Fig. 10, *b*) it is called a *converging beam*: if the rays are parallel (Fig. 10, *c*) the beam is called a *parallel beam.* A very narrow beam is called a **pencil** of light. The point **F** in Fig. 10, *a* and Fig. 10, *b* where the rays diverge from, or converge to, is called the **focus.**

2. Shadows.—The formation of shadows is really due to the fact that light travels in straight lines. Suppose **B** (Fig. 11) is a wooden ball, **L** a lamp, and **S** a cardboard screen, and we will first take **L** to be a luminous *point.* The conical beam of light **LBB′** from the lamp is stopped by the ball and the space beyond, formed by the continuation of the cone, is screened from the light: thus a circular "shadow" **SSS** is formed on the screen.

If the source of light **L** is not a luminous point but a luminous body matters become a little more complicated. Thus suppose **SS′** (Fig. 12) is a spherical source of light and **OO′** our wooden ball. Draw the rays **SO***u* and **S′O′***u* enclosing

SS′ and **OO′**, and imagine this done right round **SS′** and **OO′**. Evidently all the rays forming this beam are stopped by the ball, no light reaches the part of the screen *uu*, so that here we have a *total shadow*, circular in shape, which we call the **umbra**. An eye placed anywhere in the umbra would not be able to see the source of light **SS′** at all.

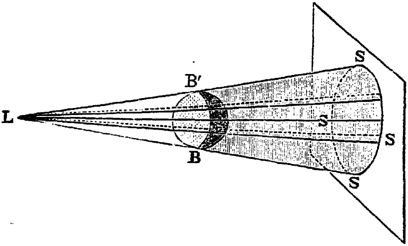


Fig. 11.

Now draw the rays **S′O***p* and **SO′***p*, and imagine this done right round **SS′** and **OO′**, thus giving a larger circle on the screen. The portion of this circle which forms a ring round the umbra is a *partial shadow*, and is called the **penumbra.** An eye placed anywhere in the penumbra would be able to see a portion of the source of light.

The "blackness" of the shadow at any part of the penumbra depends on how much of the source cannot be seen from that part. Thus just outside the umbra very little of the source would be seen: to an eye at *e* all the source below *eV* would be invisible, but all above *eV* would be seen: to an eye just outside the penumbra all the source would be seen. The depth of the penumbra shadow, *i.e.* the "blackness" of the penumbra, therefore gradually increases from its outer edge towards the umbra.

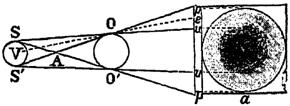


Fig. 12.

Shadows are important both in television and in all film studio work. Proper " light and shade " is necessary if objects are to be properly seen—seen, that is, in their three dimensions, length, breadth, and thickness. In Fig. 11, for example, the ball seen from the light source side would appear not as a ball but as a *flat* but light circular disc, and from the shadow side it would appear as a flat but dark circular disc: two objects may be exactly alike but may appear quite different according to the way they are illuminated and the shadows that are formed. The proper illumination and the production of shadows of the right shape and quality are therefore necessary in all work which depends on the illumination of objects by artificial light: hence the use of several lights and various reflectors in all film studios and the like.

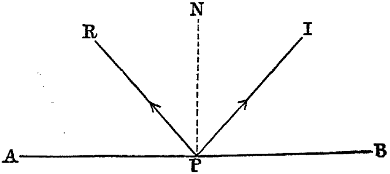
3. What happens when Light Falls on a Body.—When a beam of light falls upon the surface of a body it is, in general, broken up into three parts.

1. A portion is thrown back according to a definite law: this portion is said to be **reflected** or to suffer *regular reflection*.
2. A second portion is **scattered** or **diffused** in an irregular manner at the surface, partly back again and partly into the body. It is because of this scattering back again at the surface of non-luminous bodies that they become secondary sources of light in the presence of self-luminous bodies and become visible.
3. A third portion passes on into the body according to a definite law: this portion is said to be **refracted** or to suffer *refraction*.

A **transparent** body is one which transmits any light that enters it more or less completely, *e.g.* water, glass, mica. A body which allows little or none of the light which falls on it to pass through is said to be **opaque**, *e.g.* wood, iron. A body which transmits light to some extent but does not enable one to see clearly through it is said to be **translucent**, *e.g.* wax, china.

A smooth highly polished surface reflects most of the light which falls on it, whilst a rough uneven surface tends to scatter the light.

4. The Regular Reflection of Light.—Suppose **AB** is a polished reflecting surface and **IP** a ray of light meeting the surface at **P**: then **IP** is spoken of as the *incident ray*. Draw **PN** at right angles to **AB**: this line **PN** is spoken of as the *normal* at **P** to the reflecting surface, and the angle **IPN** is called the **angle of incidence** of the ray **IP**.



AB, Reflecting surface. **IP**, Incident rays.
PN, Normal. **PR**, Reflected ray.
IPN, Angle of incidence. **NPR**, Angle of reflection.

Fig. 13.

Now experiment shows that the incident ray **IP** is reflected along **PR** in such a way that the angle **RPN** is equal to the angle **IPN**. The ray **PR** is spoken of as the *reflected ray*, and the angle **RPN** as the **angle of reflection**. Moreover **IP**, **PN**, and **PR** are all in the same plane—in Fig. 13, in the plane of the paper. Hence we have the important *laws of reflection of ligh*

(1) The angle of incidence is equal to the angle of reflection.
(2) The incident ray, the reflected ray, and the normal are all in the same plane.

Evidently a ray of light meeting the surface at right angles, *i.e.* travelling along **NP**, will be reflected back again along the line **PN**.

Any very good reflecting surface may be called a *mirror*. The name is, however, usually confined to highly polished surfaces of a definite shape—plane, spherical, cylindrical. The ordinary plane mirror consists of a sheet of plate glass backed by a thin layer of silver which forms the reflecting surface. More recently silver *specula* have been used as

mirrors: they are formed of glass surfaces of the required shape coated *in front* with a thin layer of silver which is very highly polished.

5. The Scattering of Light.—Suppose a parallel beam of light from, say, a magic lantern in a dark room falls on a piece of "white" card fixed on the wall. It will be found that the light thrown back is not confined to one direction as in the last section, but is scattered or diffused in all directions. From *anywhere* in front the card can be seen—in fact it is brightly visible, and the room is no longer wholly dark. If a mirror had been used instead of the white card practically all the light would have been regularly reflected in some definite direction, and it could not have been seen from all positions in front.

The scattering of the light of the sun by clouds and by dust and other floating particles in the atmosphere is the cause of the difference between ordinary daylight, with its soft gradations of light and shade, and direct sunlight, with its intense light and deep shadows.

It will be seen presently that ordinary white light is made up of various coloured components—violet, indigo, blue, green, yellow, orange, red—and of these the red has a less tendency to be scattered than the violet. Hence if white light is travelling through a space containing fine particles which, of course, tend to scatter the light, we should expect the scattered light to have a violet or bluish tint, and the light which passes on a reddish tint. This is borne out by the fact that if you look towards a street lamp in a fog it appears very red, whilst the smoke from a lighted cigarette appears bluish: in looking towards the lamp you get the *transmitted* light, *i.e.* the light which has got through, whilst from the smoke you get the *scattered* light.

As we have already mentioned it is only by means of the light they scatter or diffuse that all bodies except self-luminous ones are made visible to us. If your face is in the path of the rays from a source of light, it scatters most of the light falling on it and is visible. The amount of light scattered depends on the nature of the part from which it is scattered:

thus from the dark hair, eyebrows, and parts of the face in shadow the scattered light is small: from the forehead, or teeth, it is larger, and so on. This fact is important in television.

6. The Refraction of Light.—In Fig. 14 suppose **A** represents one medium, say air, and **B** another medium, say glass, and let **PQ** be a ray of light in the air meeting the surface of the glass at **Q**. Draw the normal **NQN′** at **Q**: then **PQ** is spoken of as the *incident ray* and the angle **PQN** as the **angle of incidence.** Now it has been mentioned that in passing from **A** to **B** the ray is bent at **Q** so that the path in the glass is, say, **QR**. This bending or change of direction at the surface is called refraction, **QR** being called the *refracted ray* and the angle **RQN′** the **angle of refraction.**

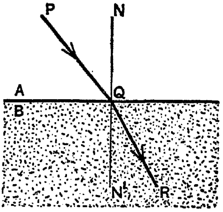


Fig. 14.

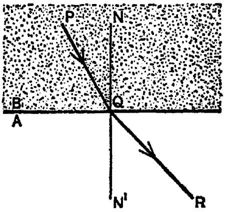


Fig. 15.

In Fig. 14 you will notice that the angle of refraction **RQN′** is less than the angle of incidence **PQN**, *i.e.* when the ray passes from air into glass it is bent *towards the normal*: this is always the case when a ray *passes into a denser medium.*

In Fig. 15 the ray **PQ** is travelling in the glass, and at **Q** it is refracted into the air along **QR**. Here the angle of refraction **RQN′** is greater than the angle of incidence **PQN**, *i.e.* when the ray passes from glass to air it is bent *away from the normal*: this is always the case when a ray *passes into a less dense medium.*

7. How a Plane Mirror forms an Image of an Object.—Consider an object **L**—say a luminous point—in front of the plane mirror **MM**. You know that an "image" of **L** can be seen in the mirror at some point **L′**—as a matter of fact **L′** appears to be just as far behind the mirror as **L** is in front—but we will just see how this comes about.

Take any ray of light **LA** and draw the normal **AN**. The ray **LA** is reflected along **AR** where the angle **LAN** equals the angle **RAN**, and to an eye at **E** the ray *appears* to come from somewhere along **RA** produced.

Now take another ray **LA′** and draw the normal **A′N′**. The ray **LA′** is reflected along **A′R′**, where the angle **LA′N′** equals the angle **R′A′N′**, and to an eye at **E** it *appears* to come from somewhere along **R′A′** produced.

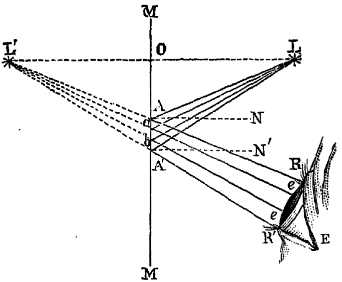


Fig. 16.

If **RA** and **R′A′** be produced backwards they meet at **L′**, which is the "image" of **L** seen in the mirror: clearly this is so, for since the image is somewhere along **RA** and also somewhere along **R′A′** it must be at **L′** where the two lines meet. It is easy to show that the image is as far behind the mirror as the object is in front.

8. What happens when Light falls on a Prism of Glass.—The "prisms" generally in use are triangular prisms of glass. Consider a ray of light **PQ** (Fig. 17) falling on one face **AB** of the prism. On entering the glass at **Q** it is bent *towards* the normal **MM′** (Art. 6) and travels through the glass in the direction **QR**. On again entering the air at **R** it is bent *away from* the normal **NN′** (Art. 6) and travels through the air in the direction **RS**. Thus whilst the original direction of

the light is **PQ**, the final direction is **RS**, *i.e.* in passing through the prism the light is turned out of its original direction or *deviated*: the deviation is away from the angle **A**, *i.e.* towards the base or broad part of the prism.

Sir Isaac Newton performed a very important experiment on light passing through a prism, which we can briefly explain in its simplest form as follows. A beam of sunlight is admitted into a dark room through a small hole **A** (Fig. 18) in a shutter or blind. The beam will be "seen" in the room as a small pencil of light diverging from **A**, and, if allowed to fall on a vertical screen at **S**, it forms a small bright spot, which is a rough image of the sun.

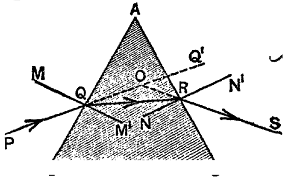


Fig. 17.

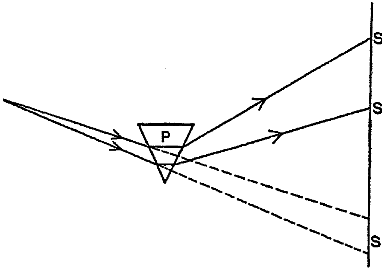


Fig. 18.

If now a prism, **P**, with its edge horizontal be placed, edge downwards, in the path of the beam, the latter will be deviated from its original path, and deflected upwards so as to form an image at **S′S″**. This image differs from that first formed at **S** in several important particulars: the vertical diameter is much longer, and, instead of appearing as a bright patch on

the screen, it is made up of several coloured bands, arranged horizontally.

This shows that the beam of *white light* incident on the prism is, on refraction through the prism, separated into its different coloured constituents, each of which forms its own image on the screen, and thus the many-coloured compound image at **S′S″** is formed. Such compound images are called *spectra.* When a **spectrum** is formed by decomposition of the sun's light, as in the case we have just considered, it is called the **solar spectrum**, and is made up of the colours—red, orange, yellow, green, blue, indigo, and violet. Of these the red rays are the least deviated, and therefore appear at **S′**, the bottom of the image **S′S″**. The violet rays are the most deviated, and are therefore found at **S″**, the top of the same image. The intermediate rays are arranged in the order given above, from below upwards, between **S′** and **S″**. We shall have more to say about these various coloured light rays later.

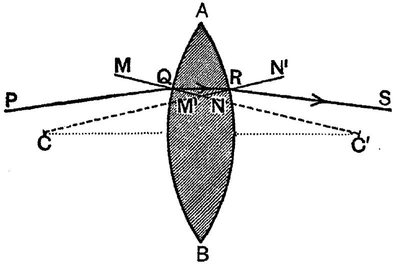


Fig. 19.

9. The Action of a Lens.—Everyone is more or less familiar with a lens, and has used one as a magnifying glass or a burning glass. As a rule the two surfaces of a lens are either both portions of spherical surfaces or one is a plane surface and the other a portion of a spherical surface.

It is usual to divide lenses into two kinds, **convex** lenses and **concave** lenses. Convex lenses are thickest at the middle,

and Fig. 19 shows one type known as a *double-convex* lens: concave lenses are thinnest at the middle, and Fig. 20 shows one type known as a *double-concave* lens. These are the only two we need worry you about at present.

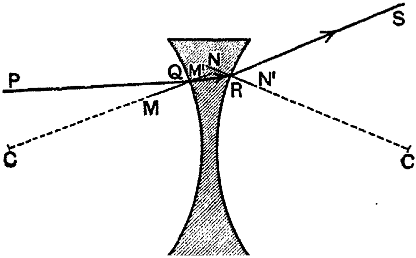


Fig. 20.

Fig. 19 also shows how a ray of light **PQ** falling on a convex lens is turned into the direction **RS**, *i.e.* towards the thicker central portion of the lens. Fig. 20 also shows how a ray **PQ** falling on a concave lens is turned into the direction **RS**, *i.e.* away from the thinner central portion towards the thicker edge of the lens. You will have no difficulty in understanding this from what has been said in Arts. 6 and 8, and by carefully looking at the construction lines shown in Figs. 19 and 20. As the convex lens is more in use than the concave we will deal with it first.

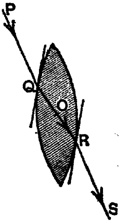


Fig. 21.

The line **CC′** (Fig. 19) joining the centres **C** and **C′** of the two spherical surfaces of the lens is called the **principal axis** of the lens. There is a point **O** in the lens (Fig. 21) such that if a ray **PQ** falls on the lens in such a way that it passes through **O**, then it comes out along **RS** parallel to its original direction **PQ**: in fact if the lens is thin we may say that a ray going through **O** simply goes straight on without being turned at all. The point **O** is called the **optical centre** of the lens.

Experiment shows that if a parallel beam of light falls on a convex lens in a direction parallel to the principal axis all the rays converge to or meet at a point **F** on the principal axis and on the other side of the lens. This is shown in Fig. 22, where the parallel beam is shown coming from the left. The point **F** is called the **principal focus**, and the distance **OF** is called the **focal length** of the lens.

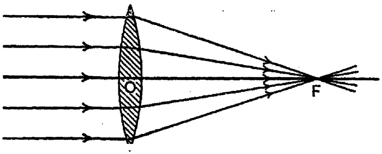


Fig. 22.

Let us now consider the formation of an image of an object by a convex lens, and we will first consider the object to be a fair distance from the lens—a distance much greater than the focal length.

In Fig. 23 (*a*) let **AB** be the object, **XX** the principal axis, **F** the principal focus, and **O** the optical centre of the lens. Now a ray **AC** from the point **A** of the object and parallel to **XX** is refracted by the lens so as to go through **F**, *i.e.* its path is the direction **CFA′**. Again a ray **AO** from the same point **A** and going through the optical centre **O**, passes straight on, *i.e.* its path is **OA′**. The point **A′** where the two rays from **A** intersect gives the image of **A**. Similarly as shown in the figure, the image of **B** is formed at **B′**, and the same applies to all points of the object **AB**. Thus **A′B′** is the image of **AB**.

Notice that in this case the image is *upside down* compared with the object and is *smaller*. Moreover, the rays forming the image *actually do pass through the points of the image* and do not merely appear to do so as was the case with the image formed by the plane mirror in Art. 7. This image formed by the lens is a *real* image, and if a screen were put at **A′B′** the image would be formed on the screen. The image of Art. 7 is called a *virtual* image, and cannot be obtained on a screen.

Fig. 23 (*b*) shows the case where the object is at a distance just equal to twice the focal length. We again have a real

image, inverted as compared with the object, but here it will be found to be *the same size* as the object: the image can be obtained on a screen.

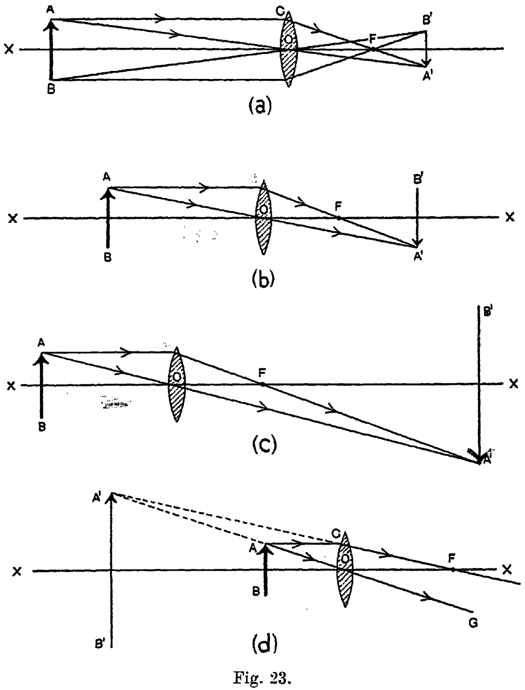


Fig. 23.

Fig. 23 (*c*) shows the case where the object is nearer the lens than in the last case, but still at a distance greater than the focal length. The image is again upside down, but it is *larger*

than the object: again it is a real image, and can be obtained on a screen.

Fig. 23 (*d*) shows the case where the object is brought still closer to the lens, its distance being now less than the focal length. The ray **AC** as before is refracted through the focus **F**, whilst **AO** through the optical centre goes straight on in the direction **OG**. Now the lines **CF** and **OG** in the figure are going away from each other and must be produced backwards to meet at **A′**. To an eye placed on the right of the lens so as to catch the rays **CF** and **OG** these rays will *appear* to come from **A′**, *i.e.* **A′** is the image of **A**. Similar remarks apply to rays from other points of **AB**, *i.e.* **A′B′** is the image of **AB**.

Notice that in this case the image is *erect*, not inverted, and is *larger* than the object: it is moreover a *virtual* image (the rays **CF** and **OG** do not actually intersect at **A′**, but only appear to do so), and cannot be obtained on a screen.

It will be noted that Fig. 23 (*d*) really shows the use of the lens as a magnifying glass. The eye is placed close to the lens and on the right of it in the figure, and the distance between the lens and the object **AB** is slightly altered until a distinct enlarged virtual image is seen at **A′B′**.

Again, Fig. 22 indicates how a lens may be used to obtain a parallel beam of light. If a source of light be put at the focus **F** a diverging beam falls on the lens and then comes out of it as a parallel beam.

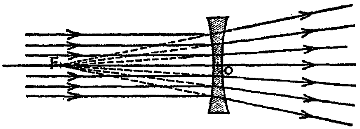


Fig. 24.

Turning now to the concave lens, if a parallel beam of light falls on it in a direction parallel to the principal axis all the rays *appear* to diverge from a point **F** on the principal axis and on the same side of the lens. This is shown in Fig. 24, where the parallel beam is coming from the left. **F** is the principal focus in this case, and **OF** is the focal length of the lens. Note particularly that in both Fig. 22 and Fig. 24 the source

of light is on the left, but **F** in Fig. 22 is on the right of the lens, whilst in Fig. 24 it is on the left.

Fig. 25 shows the formation of the image **A′B′** of the object **AB**. The ray **A**a is refracted along aa' such that $a'a$ produced backwards passes through **F**. The ray **A**o goes straight on. An eye placed so as to catch these two rays sees an image of **A** at **A′** where they appear to intersect. The same reasoning applies to other points of **AB**, *i.e.* **A′B′** is the complete image.

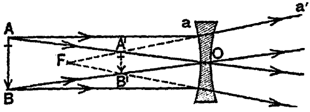
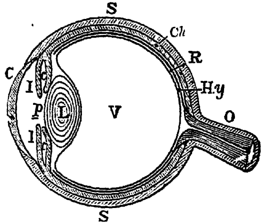


Fig. 25.

The image formed in this case is clearly a *virtual* one, and it is *erect* and *less* than the object. This is always so with a concave lens, and we need therefore not consider any further positions of the object.

10. The Human Eye.—Fig. 23, (a) really shows the principle on which the human eye works.

The eye (Figs. 26 and 27) consists of a curved transparent surface in front called the **cornea**, a double convex lens called the **crystalline lens**, protected in front by a circular curtain called the **iris** which has a central opening called the **pupil**, and finally a sensitive screen at the back called the **retina**, on which the images of outside objects are formed. The iris is the coloured ring round the pupil.



C = Cornea. L = Crystalline Lens.
R = Retina. I, I = Iris. p = Pupil.
Fig. 26.

For distinct vision of any object a *clearly defined* image of it must be formed on the retina. Fig. 27 represents such a case. The rays of light from the object **AB** are refracted on entering the cornea and on passage through the crystalline lens, and form an image

ab on the retina. The image is upside down as compared with the object, but the stimulus conveyed to the brain is so "understood" by the brain that we "see" the object erect.

Under ordinary conditions it is evident that, with an eye as above described, only objects at a certain definite distance from the eye can be seen distinctly; for as the distance between the image and the lens is fixed, the distance between the object and the lens must also be fixed. We know, however, from experience that objects can be seen distinctly by the normal eye at all distances greater than a certain "least distance" known as *the distance of nearest distinct vision*. This is due to the power of *accommodation* possessed by the eye; the muscle attached to the lens is able to alter the curvature of the surfaces of the lens, making the front surface much more convex, and bringing the lens as a whole nearer to the cornea; thus the focal length is *accommodated* to the distance of the object on which the eye is focussed.

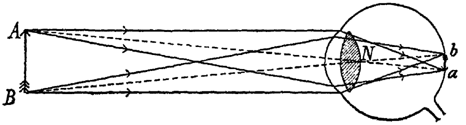


Fig. 27.

The retina is a close network of nerves and blood vessels —an extension of the optic nerve O which conveys the impression to the brain—but it is very complex in structure. It really consists of about ten layers of tissue. The second layer from the surface contains some strange bodies called *rods* and *cones*. In the outer parts of the rods is a fluid called the *visual purple*.

There are three important regions of the retina which we must mention. One is a slightly raised small region of a yellowish colour which is very sensitive to light: it is called the *yellow spot*. Another is called the *fovea centralis*: it is a slight depression at the summit of the yellow spot, is very rich in rods and cones, and is the most sensitive spot on the retina. Another has no rods or cones and is not affected by

light: it is called the *blind spot*, and marks the place where the optic nerve enters the eye. When we look at any object we move the eye-ball by the muscles controlling it so as to bring the various parts of the image of the object on to the fovea centralis—the most sensitive spot.

11. Persistence of Vision.—It may be said that television depends upon a certain property of the human eye which we are almost unconscious of, namely, that any impression produced on the retina does not disappear immediately the cause of it is made to disappear, but remains on the retina for a short time—in other words the impression of the image on the retina does not disappear immediately the object is taken away: the impression lasts for about one-sixteenth to one-tenth of a second. This property is called "persistence of vision," and both television and the cinema depend upon it.

There are many simple illustrations of this persistence of vision. Thus if a match with its end glowing be rapidly moved round in a circle we do not see a bright point changing its position, but a continuous circle of light.

If a bird be drawn on one side of a piece of cardboard and a cage on the other side, and the card be rapidly rotated by strings fastened to two opposite edges of the card, the bird will be seen inside the cage: in this case we get, say, first the image of the cage on the retina and then before this impression has disappeared we get the image of the bird, and so on: hence the bird and cage are "seen" together.

The film used at the cinema theatre is made up of a large number of small photographs each of which pictures a motion just slightly after the one in front of it. With these run through the projector at a rapid rate, say sixteen or more complete pictures per second, the appearance on the screen is that of continuous movement and not a jerky movement of still pictures one after the other.

Imagine we have a chess-board with black and white squares hung up on the wall in a dark room, and suppose that we have a lantern from which we can direct a narrow beam of light on the board—say a beam which just covers one square. Now imagine the beam moved slowly along one

row of squares: we will see first a dark square, say, then a white one, then a dark one, and so on, *i.e.* one square at a time. Suppose now the beam moves along the row quickly say in $\frac{1}{16}$ of a second: we would, by persistence of vision, see the whole row at one time. Imagine now that the beam could be made to traverse the whole board in this way in $\frac{1}{16}$ of a second, and that it kept on doing it 16 times per second: we would see the whole board complete on account of our persistence of vision.

Suppose your friend is standing against the wall and that the narrow beam of light is projected on to his face. Imagine this light spot is moved quickly downwards over his face: then suppose it is moved quickly downwards again, but that this second journey is a little more to the right, the vertical edge of this second spot-light journey just touching the vertical edge of the first journey: then suppose a third downward journey is made displaced again a little more to the right, the vertical edge of this third spot-light journey just touching the vertical edge of the second one, and so on.

Finally, imagine these vertical journeys to take place so rapidly that the whole face is covered in $\frac{1}{16}$ of a second, and that the operation is kept going on at the rate of 16 complete "scans" over the face per second: then the whole face would be visible by our persistence of vision. As you will see presently this is what is done in television.

If you cover a screen with "luminous paint," throw a bright patch of light on the screen from a lantern, and then remove the light beam, the "image" will remain on the screen for a time, gradually fading away. It is possible that the visual purple in the rods of the eye acts in some way similar to this paint, and causes our persistence of vision. Without persistence of vision we would have no cinemas—no television.

CHAPTER III.

A GLANCE AT SOME OF THE APPARATUS USED IN TELEVISION.

1. Conductors and Insulators.—There are many separate pieces of apparatus in a receiving set whether used for the reception of " sound " alone or, as in the case of television, of both sound and " vision," and unfortunately the technical names of some of these—inductance coil, condenser, high frequency transformer, low frequency transformer, choke, grid leak, neutrodyne unit, scanning disc, neon tube, phonic wheel, etc.—are most alarming to a beginner. However, you must known something about them, how they are made, how they work, why they are used, and you will find that, after all, they are very simple things and there is really nothing to be afraid of. In this chapter we will deal with some of these: others we will deal with when we want them.

In electrical science a **conductor** is a substance which readily allows electricity to flow through it, and an **insulator** is a substance which does not. The best conductors are the metals, and of these annealed silver stands first. Amongst the good insulators are dry air, dry glass, paraffin wax, amber, mica, ebonite, shellac, indiarubber, silk, porcelain, sealing wax, etc.

The difference between a conductor and an insulator is due to the condition of their electrons. An atom of a conductor contains certain electrons that are comparatively loosely bound to the nucleus or protons: they are fairly easily torn out when an electrical pressure difference is set up at the ends of the conductor, and readily take part in the flow of electrons through the conductor. In the atoms of an insulator the electrons are, in comparison, tightly bound, and therefore not easily detached: hence they do not " flow along " as a conductor's electrons do.

Of course, if the electrical pressure be big enough the electrons of an insulator may be dragged from the atoms so that the insulator begins to conduct. Heating an insulator or allowing moisture or dust to collect on its surface also spoils it.

In receiving sets for the usual "wireless" and television copper, aluminium, and brass are the chief substances used as conductors, and shellac varnish, paraffin wax, mica, and ebonite are usual insulators.

2. Primary Batteries. The Dry Cell Battery.—If a plate of zinc and one of copper be put side by side in a dilute solution of sulphuric acid a certain chemical action ensues which results in the copper being at a higher potential than the zinc. If then the copper and zinc be joined by a wire (Fig. 28) an electronic current will flow through the wire from the zinc to the copper, or adopting the older idea, a (conventional) current, indicated by arrows in the figure, will flow from the high potential copper to the low potential zinc. The chemical action keeps up the potential difference between the plates so that the current keeps on flowing although it gradually weakens (see below).

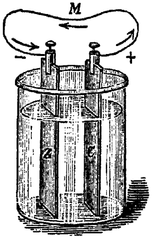


Fig. 28.

Such an arrangement is called a simple **primary cell.** The copper is called the high potential plate, and the portion of it outside the liquid is called the *positive pole*. The zinc is called the low potential plate, and the portion outside is called the *negative pole*.

Now "how and why" the chemical action in the cell sets up a potential difference between the plates is interesting, but it would mean a very lengthy explanation, and it is really not necessary for a beginner to know this detail. Briefly, as a result of the chemical action we have an excess of negative electrons piled up at the zinc, and at the copper an excess of positive ions, and thus we have a difference in electrical pressure established between the plates. When the wire **M** is put there, off go the electrons in the manner explained in

Art. 3 of Chap. I. to the positive ions waiting for them (constituting the electric current); but the chemical action keeps up the supply of electrons at the zinc and positive ions at the copper, and so the flow continues. This explanation will suffice for the present.

It frequently happens that one cell is not sufficient to do what we want, and in that case we join several together, the positive pole of one being generally joined to the negative pole of the next. Such an arrangement is called a **battery,** and the cells are said to be joined in *series*.

One drawback to the above cell is that the chemical action of the acid on the zinc causes hydrogen gas to be liberated and bubbles of the gas stick *to the copper plate.* This is called *polarisation,* and it spoils the cell partly because hydrogen has a big resistance, and partly because it lessens the pressure difference between the plates. Modern cells are mainly devices to get rid of polarisation.

The pressure difference between the zinc and the copper before the wire **M** is put to join the poles is called the **electromotive-force** (E.M.F.) of the cell. If, say, six cells are in series the E.M.F. is six times that of one cell.

There are many cells on the market known as **dry cells.** One type, shown in Fig. 29, consists of a zinc cylinder **Zn** next to which is a paste **W** composed of plaster of Paris, flour, zinc chloride, sal-ammoniac, and water. Adjoining this is a second paste **B** of carbon, manganese dioxide, zinc chloride, sal-ammoniac, and water. **C** is a rod of carbon, forming the high-potential plate of the cell. The whole is covered with a case of millboard, is sealed with pitch, and is provided with a vent for the escape of gas. The manganese dioxide " uses up " the hydrogen and more or less prevents polarisation. The E.M.F. is about 1·4 volts.

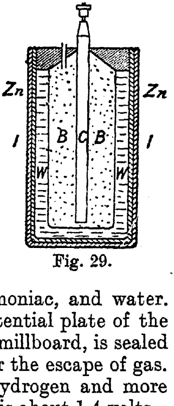


Fig. 29.

In valve receiving sets used for ordinary wireless, dry cells in series are extensively employed for what is called the **high tension (H.T.) battery**—a battery which is used to apply a

high positive potential to the *plates* of the valves (Chap. VI.). Such batteries may have an E.M.F. of from 20 volts to 200 volts or more, according to circumstances, and as the E.M.F. of a single dry cell is of the order 1·4 volts, it will be seen that the number of cells in a high tension battery will vary from, say, 15 or 16 to quite large numbers. You probably use in your wireless receiver at home 60, 80, 100, or 120 volts in your H.T. battery of dry cells, according to the kind of valves in your set.

In receiving sets for television dry cells are also used for the H.T. battery, but here a bigger voltage is necessary—of the order up to 320 volts or so—and moreover the battery must be what is called a *high capacity* battery—the very small dry cells sometimes used with wireless sets will not do. Several suitable makes of H.T. batteries for television work are on the market.

High tension batteries are usually neatly arranged in strong cardboard boxes, the cells being well sealed in with paraffin wax or pitch. Tappings are taken from every third or fourth cell and connected to a hollow metallic socket, the upper open end of which projects above the wax or pitch. The positive and negative battery leads from the receiving set are attached to metallic pins, known as **wander plugs**, which fit into these sockets: in this way the voltage actually used can be varied. Graduated scales alongside the sockets indicate the voltage which is being tapped. Fig. 30

Fig. 30.

It is nearly always necessary in receiving sets, whether for ordinary wireless or television, to apply a small positive or negative potential (from 3 to 18 volts or so in practice according to the type of valve) to the *grid* of a valve (Chap. VII.): invariably this is done by means of a few dry cells, the latter being then referred to as a **grid biasing battery.**

3. Accumulators.—**Accumulators** or **Secondary Cells** use lead plates in dilute sulphuric acid: they differ from primary cells in construction and also in this respect: Accumulators must first be "charged," as it is termed, by passing a current through them from another battery (or dynamo), the positive pole of the charging battery being joined to the positive pole of the accumulator and the negative pole of the charging battery to the negative pole of the accumulator during this process. After being sufficiently charged the accumulator itself will give a current, the direction of the *conventional* current which it gives being from the positive pole to the negative pole through the outside circuit. In time the accumulator "runs down," *i.e.* becomes too weak to deliver a current, and then it must be re-charged.

You will understand the principle of the action of the accumulator from the following. In Fig. 31 **A** and **K** are two lead plates in dilute sulphuric acid. The plate **A** (which will be the positive pole of this accumulator) is joined to the positive pole of the charging battery on the left, and the plate **K** (the negative pole of the accumulator) is joined to the negative pole of the charging battery. **V** is a voltmeter—an instrument for measuring the pressure in volts.

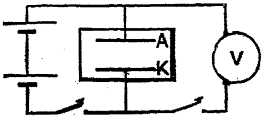


Fig. 31.

Close the key on the left: the charging current passes. This decomposes the acid and liberates two gases, hydrogen and oxygen. The oxygen appears at **A** and it acts on the

to the surface. Thus when the accumulator is charged we still have the lead plate **K**, but the surface of **A** is well coated with lead peroxide.

If now you open the key on the left, thus cutting out the charging battery, and close the key on the right, thus joining the voltmeter **V** to the accumulator, you will find that the accumulator gives a current—a *conventional* current from **A** to **K** outside. The voltmeter will read about 2 volts at first but the reading will get gradually less, and after a time it will have dropped to zero. The accumulator is now completely "discharged," and it will be found that the lead peroxide at **A** has disappeared, and that both plates are coated with what is called lead sulphate.

If you now disconnect the voltmeter and once more join up the charging battery, the lead sulphate at **A** will be converted into lead peroxide, and that at **K** into lead, so that the accumulator will again be in its charged condition ready to give a current.

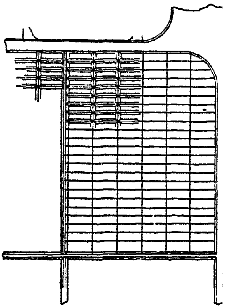


Fig. 32.

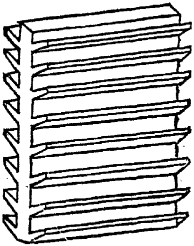


Fig. 33.

In practical accumulators solid lead plates are frequently replaced by lead plates cast in some form of grid, the grids being packed with a suitable paste, say a paste of red lead and sulphuric acid. The main principle of the action is much the

same as that outlined above, but the actions during charge and discharge are more perfect and the accumulators more efficient.

There are many types of accumulator plates on the market. Fig. 32 shows one type of negative plate and Fig. 33 one type of positive plate of the **E.P.S. accumulator.** The paste for the negatives is made of pure well-ground litharge and sulphuric acid of specific gravity 1·2 (cold): the paste for the positives consists of red lead and sulphuric acid of specific gravity 1·1 (cold).

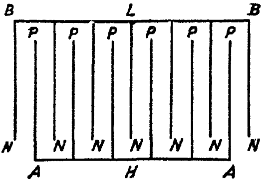


Fig. 34.

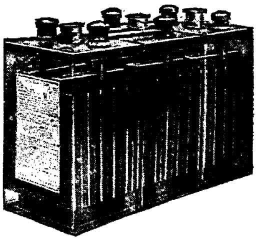


Fig. 35.

Fig. 34 shows how the plates in an accumulator are arranged. This depicts a large 13 plate cell consisting of 7 negative plates **N** all joined together and 6 positive plates **P** all joined together. The plates must be raised a little from the bottom of the containing vessel so that the space may hold any active material which may fall from the plates and prevent it from joining two opposite plates, thus "short-circuiting" and spoiling the cell. Further, as opposite plates are very close together some type of separator—glass tubes, ebonite forks, thin sheets of special wood, etc.—should be put between them to prevent internal contact.

The **Exide accumulator battery** for wireless work is shown in Fig. 35. This shows a 6 volt battery consisting of three accumulators in celluloid boxes, the three boxes being cemented together. Thin wooden separators (see above) are used between the plates.

The **Hart accumulator battery** is an excellent one, and we can from our own personal experience, strongly recommend it to all wireless workers. The plates are particularly robust, and the cells very steady and lasting in their performance.

Accumulator batteries such as the above are mainly used in receiving sets for heating the *filaments* of the valves (Chap. VI.); when so used they are referred to as **low tension (L.T.) batteries.**

An accumulator battery can also be used in television receivers for driving the small motor which is a necessary part of the "televisor." The voltage required depends on the type of motor: thus the Vidal Engineering Co. turn out a series of small television motors to run off accumulators of 6-12 volts and giving from 2 to 3 amperes. A battery of small accumulators can also be used as a H.T. battery for television, and in many respects is better than a dry battery. Other uses of the accumulator will be given later.

For reasons which we need not explain, it damages an accumulator if it is over-discharged. The specific gravity of the acid is a good guide as to the condition of an accumulator: in a general way (1) when fully charged the specific gravity is about 1·25, (2) when half discharged it is about 1·18, and (3) when fully discharged it is about 1·15. When fully charged the E.M.F. is just a little over 2 volts, and when this drops to 1·8 volts the cell should be regarded as discharged. An accumulator should never be allowed to remain in an uncharged condition, for this also impairs the cell.

The **capacity** of an accumulator is measured in what we call *ampere-hours* (amperes $\times$ hours); thus if a large accumulator has a capacity of 704 ampere-hours and the greatest discharge current as stated by the makers is 64 amperes, it will be able to give this current for 11 hours. For most purposes accumulators are designed to give a certain current on a 9 or 10 hour discharge rate, *i.e.* the best results are obtained if the current taken from the cell be such that it is completely discharged in 9 or 10 hours. Thus if an accumulator is stated to have a capacity of "30 ampere-hours actual," then assuming the 10 hours basis, since $\frac{30}{10} = 3$, good results will be obtained by taking a current of not more than 3 amperes from the cell.

4. Photo-Electric Cells.—This piece of apparatus is used at the "sending end" in television, not in the receiver, but it is advisable to deal with it at this stage.

The **photo-electric cell** is one of the essential things in television, for it enables us *to change from a varying light scattered by the object which is to be "televised" to a varying current of electricity*, and then this varying current is handled in the same way as we handle the varying currents in the wireless broadcasting of speech, music, etc. How all this is done you will understand presently.

Hertz, in 1887, and then Hallwachs, in 1888, noticed that when light of a certain kind fell upon certain metals which were negatively charged, *i.e.* had a surplus of negative electrons, the metals lost their charge, and this could only be due to the fact that the light tore out negative electrons from the metals. This effect was called *photo-electric emission* or the *photo-electric effect.* Positively-charged metals, as might almost be expected, did not show the effect, *i.e.* did not show any loss of charge when the light fell on them.

The explanation of the tearing of the negative electrons away from the metal by the light is probably that the aether disturbance known as light sets the electrons in the metal in such violent agitation that finally the amount of their movement becomes so great that they are ejected out of the metal and repelled away.

The early experimenters mainly used negatively charged plates of zinc and aluminium, and the light they used was of the violet type. Further experiments soon showed that the metals *potassium*, *rubidium*, and *caesium* gave the best results with *ordinary* light, especially when they were treated in a certain way. Photo-electric emission is also well shown by sodium, lithium, strontium, and barium.

Now let us see how we can make use of these facts to construct a "cell" or device which will throw out electrons and therefore give an electric current at any moment according to the amount of light which happens to be projected on it at that moment.

Suppose **A** (Fig. 36) is the sensitive metal plate—a copper or silver plate coated with potassium on the right hand face in

gases, generally *argon* or *helium* at a low pressure of about $\frac{1}{6}$ of a millimetre of mercury, *i.e.* roughly $\frac{1}{5000}$ of the pressure of the atmosphere, and the cell is referred to as a *gas-filled cell.* In a vacuum cell the current through the cell is that carried by the electrons liberated from the cathode: in a gas-filled cell some of the electrons from the cathode collide with the gas particles and detach more electrons, and these additional electrons are added to the original flow. The gas-filled cell is more sensitive and gives a bigger current for a given amount of light, but the vacuum cell is more constant in its action: for television gas-filled cells are mainly used.

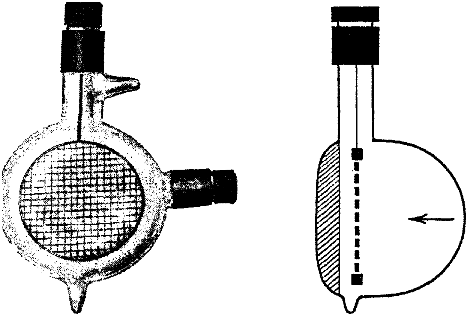


Fig. 37.

A form of photo-electric cell largely used consists of a glass bulb rather flat at one side (Fig. 37). This flat side is covered on the inside with a thin deposit of copper or silver, and then on this is deposited a layer of potassium or caesium: this forms the sensitive plate or cathode. In front of the cathode is a metal ring covered with a grid of fine wires: this forms the anode. The light is projected into the cell in the direction indicated. Connections to the anode and cathode are made by two platinum wires fused through the glass. The standard Osram photo-electric cell, made by the General Electric Co., follows this pattern.

the figure. Suppose **B** is a metal grid facing the potassium on **A**, and further suppose **A** is joined to the negative pole and **B** to the positive pole of a battery, so that **A** has a surplus of negative electrons or is negatively charged, and **B** has a surplus of positive ions or is positively charged. We will suppose **A** and **B** to be in a glass globe from which the air has been exhausted. There is, of course, no current passing across the space between **A** and **B** because the space is an insulator: in fact **A** and **B** are, as it were, merely the two "poles" of the battery sticking out but not joined, *i.e.* the circuit of the battery is not closed and there is no current.

Now suppose a beam of light from a lamp is projected through the grid **B** on to the potassium face of **A**. Negative electrons will be dragged out of **A**: these electrons will be repelled by **A** and attracted by **B**, and will rush off towards **B** so that a continuous *electronic* current will be flowing in the circuit in the direction **A** to **B** through the space between the plates, and from **B** through the battery to **A**. Moreover an intense beam of light ejects more electrons and therefore causes a bigger current to flow than a beam which is not very strong. Thus if the light projected on to **A** is light scattered from your brow (your face being illuminated, say, by a narrow beam from an arc lamp) the current will be bigger than if it is light scattered from your dark hair.

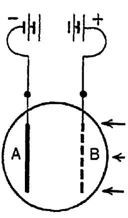


FIG. 36.

The photo-electric cell then is a device which starts a current when light falls on it, and the current stops when the light is taken away. Further, there is no delay in starting and stopping: the current starts *at once* when the light falls on the plate, and stops *at once* when the light stops. Moreover, the current varies in strength almost exactly in proportion to the intensity of the light falling on the sensitive plate.

In one type of photo-electric cell, **A** (generally spoken of as the *cathode*) and **B** (spoken of as the *anode*) are in a glass globe from which all the air has been withdrawn, *i.e.* **A** and **B** are in a vacuum and the cell is called a *vacuum cell.* In another type the glass globe contains, not air, but one of the inert

gases, generally *argon* or *helium* at a low pressure of about $\frac{1}{6}$ of a millimetre of mercury, *i.e.* roughly $\frac{1}{5000}$ of the pressure of the atmosphere, and the cell is referred to as a *gas-filled cell.* In a vacuum cell the current through the cell is that carried by the electrons liberated from the cathode: in a gas-filled cell some of the electrons from the cathode collide with the gas particles and detach more electrons, and these additional electrons are added to the original flow. The gas-filled cell is more sensitive and gives a bigger current for a given amount of light, but the vacuum cell is more constant in its action: for television gas-filled cells are mainly used.

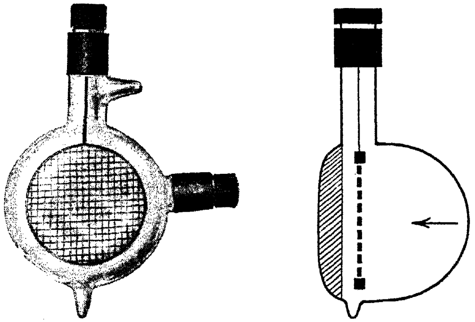


Fig. 37.

A form of photo-electric cell largely used consists of a glass bulb rather flat at one side (Fig. 37). This flat side is covered on the inside with a thin deposit of copper or silver, and then on this is deposited a layer of potassium or caesium: this forms the sensitive plate or cathode. In front of the cathode is a metal ring covered with a grid of fine wires: this forms the anode. The light is projected into the cell in the direction indicated. Connections to the anode and cathode are made by two platinum wires fused through the glass. The standard Osram photo-electric cell, made by the General Electric Co., follows this pattern.

An improved type of photo-cell made by the General Electric Co. is shown in Fig. 38: it is a gas-filled type cell, and its construction will be understood from the figures. As already mentioned, this Company use potassium on copper in their standard practice, but in this, caesium deposited on oxide of silver has also been used: in its best form it is ten times more sensitive than the potassium on copper cell.

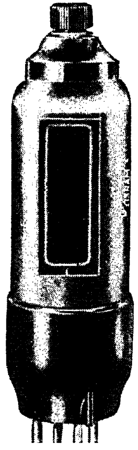


Fig. 38.

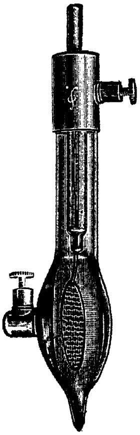


Fig. 39.

Two more types of cells are shown in Figs. 39 and 40. The battery pressure required varies from about 50 volts in the case of the vacuum cells to 150 or 200 volts in the case of gas-filled cells. These two cells are made by Isenthal & Co.

The actual making of the photo-electric cell is a lengthy business, for the metals oxidise so quickly in air that the cathode cannot be made in the air and then be put into the globe: the cathode has, as it were, to be made *in the globe*. Different methods are used with different makes of cells.

Thus one method is to introduce the metal as a vapour and then to condense it where it is wanted. Frequently the sensitiveness is increased by filling the globe with hydrogen gas at a low pressure and then forcing an electric discharge between the anode and the cathode. But all these points are details which need not be worried about just now.

5. **The Neon Tubes or Lamps.**—The neon tube or **neon lamp**, as it is called, is another essential thing in television, for it enables us *to change from a varying current of electricity to a varying amount of light, say, on a screen.* It works therefore in the opposite way, in practice, to the photo-electric cell: the latter changes from a varying light to a varying current, the former from a varying current to a varying light. The neon lamp is, of course, used at the "receiving end," *i.e.* is a part of the receiving set.

Fig. 40.

Neon is one of the rare inert gases in the atmosphere—forming about one eighty-thousandth part of it—the other inert gases in the atmosphere being argon, helium, krypton, and xenon, and it has the peculiar property that if rarefied neon is contained in, say, a glass tube closed at the ends, with a piece of platinum wire fused through the glass at each end, and if an electric discharge be passed through it the whole tube glows with a rich red orange light.

You have probably seen neon tubes used for advertising purposes often of a "stunt" character. Letters and figures are made of glass tubing and the tubes contain rarefied neon; a high pressure alternating current is applied to the terminals or electrodes leading into the tubes, with the result that the letters and figures are strikingly illuminated.

For many years we have been experimenting on passing electric-discharges through rarefied gases contained in glass tubes. Thus as far back as 1877 Sir William Crookes did the experiments, and later workers got some very interesting

results. Thus with fairly low gas pressures the discharge was found to take the form of a luminous column stretching almost the whole length of the tube. This was called the positive column, and its colour depended on the gas in the tube: with air-red, hydrogen-blue or red, nitrogen-red, carbon dioxide-white. At still lower gas pressures the positive column was found to break up into alternate bright shells and dark patches, and finally a condition was reached where the anode gave out the peculiar rays known as X-rays.

However, of all the gases that have been tried, neon is best suited for television purposes because it responds *instantly* to any change in the current, and the light or illumination it gives is definitely related to the current—a " big " current gives immediately a " big " illumination and a " smaller " current a " smaller " illumination.

Suppose we have two metal plates **A** and **B** parallel to each other and say about 2 millimetres apart in a glass vessel containing rarefied neon, the plates having platinum wires attached to them which pass through the glass for connecting purposes. Let **A** and **B** be now connected to a powerful battery, **A** to the positive pole and **B** to the negative pole, so that **A** is the anode and **B** the cathode.

Now at a certain *gas pressure* the tendency of a discharge is to go from the back of one plate to the back of the other and not confine itself to the narrow space between the two plates. It requires an electric pressure to be applied to the terminals of **A** and **B** of the order of about 200 volts (called the **starting voltage**) to start this discharge, and when it does begin the back of **B**—the negative electrode or cathode—becomes coated with a yellowish orange colour. If when this steady glow is on we suddenly increase the voltage applied to **A** and **B** the glow becomes more intense, and if we lessen this extra voltage the glow becomes less intense. The glow increases and decreases as we increase and decrease the extra voltage applied over and above the starting voltage, and moreover the change in illumination occurs immediately we change the voltage—there is no waiting—no lag.

As will be seen later it is on the plate **B** of a neon lamp that we " see " the image which is being transmitted in television.

We saw in Chapter II. that a body giving out light is usually heated, *e.g.* the filament in a glow lamp is heated by the current going through it, but the light from a neon lamp is not directly due to heating—it is due to something entirely different. The full explanation of the why and the wherefore of the light production in the neon lamp is rather too lengthy to be given here, but briefly we may tell you this: There are always a few free electrons wandering about in a rarefied gas, and when the terminals of the neon tube are joined to the 200 volt battery these negative electrons immediately rush off towards the positively charged plate—the anode.

In their mad rush they encounter the atoms of the gas: in some cases the rushing electron may go right through the atom without doing anything: in other cases it may knock an electron out of the atom in its mad rush. The ejected electron may go back to its home in the atom when the disturbing electron has passed on, or it may find the attraction of the positive anode greater than that of its home and rush off towards it, colliding with atoms and knocking out other electrons in its rush.

Moreover, in rushing along electrons may join up with other atoms for a time, and further, atoms which have lost an electron, and which are therefore positively charged, set off towards the cathode which is negatively charged, and in their rush they also may upset other atoms with which they collide. Accompanying all this turmoil there is, of course, a movement of electrons towards the anode (and positive ions towards the kathode), constituting the electric current through the lamp.

Now all this business, the knocking out of electrons (termed *ionisation*), the re-joining-up or *recombination*, and the giving up of electrons and ions to the electrodes, is very complicated, and we can only say here that it is where ionisation and recombination are taking place, that the movements of the electrons set up the aether disturbances which give rise to the sensation of sight and produce the illumination seen in the neon lamp.

There are various types of neon lamps on the market, but the one known as the plate type is perhaps most suitable for getting television at home. One form, in which the electrodes

are of nickel or iron, is shown in Figs. 41 and 42, and the construction will be readily understood from the figures. Remember that the tube contains rarefied neon, and that each electrode communicates with an outside terminal by a platinum wire fused through the glass. The electrodes and tube undergo special treatment in manufacture to ensure that no foreign gas remains in the material, for the presence of these would upset the picture.

6. Capacity and Condensers.—It might almost be said that there are two essential properties of a wireless installation, for it is upon two properties that something you will have heard about so much—*the wave length of the wireless wave*—depends. One of these properties is connected with a **condenser**: the other is dealt with in Art. 7. The *exact* theory of the action of a condenser is not altogether easy to explain in simple language, but the following is as much of it as you will require at present.

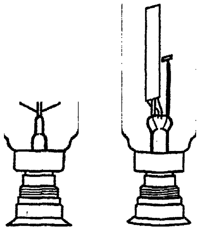


PLATE TYPE NEON.
Fig. 41. Fig. 42.

A condenser merely consists of two metal plates placed parallel a short distance apart with a very good insulator in between them. The insulator is called the **dielectric**, and the plates are frequently called the **coatings** of the condenser. Two sheets of tin foil pasted on opposite sides of a somewhat larger sheet of glass is a simple condenser.

Now let **A** and **B** (Fig. 43) be the two plates of a condenser, and let **A** be joined to the positive pole and **B** to the negative pole of a battery. As soon as the connections are made there is a momentary rush of electrons (negative) from the negative pole of the battery to **B**, and electrons rush out of **A** to the positive pole: this really takes place in the manner explained

in Art. 3 of Chapter I. Thus on **B**, the negative plate of the condenser, we have an excess of electrons, whilst on **A**, the positive plate of the condenser, we have atoms which each have lost an electron—positive ions as they are called.

The positive ions of **A** and the negative electrons on **B** attract each other with an intense force. The army of electrons on **B** is anxious to get across the dielectric to make up the deficit of electrons in the positive ions of **A**, and the positive ions of **A** are just as eager to have them.

Now the electrons on **B** cannot get across the dielectric to **A**, but they do, as it were, the next best thing—they *try* to drive electrons out of the atoms of the dielectric (themselves taking their place), leaving these evicted electrons to drive out other electrons and take their place, and so on until finally electrons would reach **A**. At the same time the positive ions of **A** are assisting in the good work by trying to pull out the electrons and to repel the resulting positive ions in the dielectric.

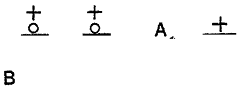


Fig. 43.

The dielectric, however, is a substance which clings to its electrons. All that happens therefore is that the " tracks " of the electrons round the positive centres (or protons) in the atoms of the dielectric are *strained* as shown in Fig. 43: the positive nucleus of any dielectric atom is pushed by **A** and pulled by **B** down towards the electrons on **B**, and the electrons in any dielectric atom are pulled by **A** and pushed by **B** up towards the positive ions of **A**. The final state of affairs is that the plate **A** has a large positive charge and **B** a large negative charge, *the medium is strained*, and we have what is spoken of as a *charged condenser*, but no " flow of current " across the dielectric.

The electric lines are shown in the right hand side of the figure. Compare these with Fig. 4.

The plate **A** is at the same potential as the positive pole of the battery, and **B** is at the same potential as the negative

pole of the battery once the momentary rush of electrons has taken place. But from our point of view the important thing to notice at present is that owing to the nearness of the negative electrons on **B**, the plate **A** has more positive ions on it, *i.e.* has a bigger positive charge, than it would have if **B** were not there, and similarly **B** has more electrons on it, *i.e.* has a bigger negative charge, than it would have if **A** were not there. The condenser in fact has enabled us to collect big charges.

We often speak of the **capacity** of a condenser, and by this we really mean the amount of electricity which the plate **A** would be carrying if the potential difference between the plates **A** and **B** were one volt, and the unit of capacity is called a **farad**: thus we say *the capacity of a condenser is so many farads, or so many microfarads*, a microfarad being one-millionth of a farad. The larger the plates, the nearer they are together, and the better the dielectric the bigger is the capacity of the condenser.

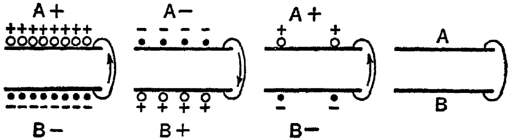
Now before going further, just thoroughly grasp the idea that anything of the nature of a condenser—two conductors separated by an insulator—anything with marked *capacity*—tends to get hold of electricity, to collect big charges. That idea will answer our purpose at present, although much more might be said about it if we want to be scientifically thorough and precise.

If the two plates of a charged condenser be connected by a wire a *discharge* takes place through the wire and the potentials of the plates become the same. This merely means that the surplus electrons on **B** " travel " along the wire (*i.e.* a current flows) and join up with the equal number of positive ions on **A**.

Actually the discharge of a condenser is rarely such a simple matter as is outlined above. To fix ideas let us imagine that we start off with a charged condenser, having, say, 8 surplus positive ions on **A** and 8 surplus negative electrons on **B** (**A** *is positively charged and* **B** *negatively charged*), and let **A** and **B** be now joined by a wire (Fig. 44).

Electrons rush round from **B** to **A**, but if the resistance is not large, so great is the rush that *more than* 8 electrons leave **B**. Suppose 12 electrons rush round from **B** to **A**. Clearly 8 of

these will satisfy and neutralise the 8 positive ions on **A**, leaving **A** with a surplus of 4 electrons, *i.e.* **A** *is now negatively charged*; similarly **B** has four positive ions, the remains of the four atoms from which the four extra electrons cleared out, *i.e.* **B** *is now positively charged*.



The arrows indicate the direction in which the electrons are about to travel.

Fig. 44.

Electrons now rush from **A** to **B**, but again so great is the rush that more than 4 electrons leave **A**. Suppose 6 electrons rush round from **A** to **B**. From the preceding it follows that **A** is left with 2 surplus positive ions, the remains of the two atoms from which the two extra electrons have been obtained, *i.e.* **A** *is again positively charged*. Similarly **B** has got two more electrons than it requires, *i.e.* **B** *is again negatively charged*.

The above actions are repeated, the rushes backwards and forwards getting less and less each time until they cease altogether, matters becoming quite normal with **A** and **B** at equal potentials. Fig. 44 depicts the results. Of course in practice it is not a matter of eight electrons and eight ions but of millions.

Such a discharge as is indicated above is called an **oscillatory discharge**, and condenser discharges of this type are used in wireless, for as already mentioned, the rapid swinging of electricity to and fro agitates the aether and the disturbance travels out in the form of aether waves with the velocity of light.

Two patterns of condensers are used in the transmission and reception of " sound " and television, viz. **fixed condensers** and **variable condensers**. You will learn in Chapter IV. how and why they are used.

One type of fixed condenser merely consists of two sheets of tin foil, one on each side of a thin sheet of mica. Another is constructed of alternate sheets of tin foil (thin lines in Fig. 45) and paraffined paper or mica (thick lines in Fig. 45), the odd sheets of foil being bunched together and joined to one terminal **A**, the even numbers being also bunched together and joined to the other terminal **B**.

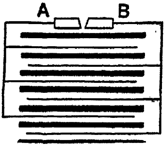


Fig. 45.

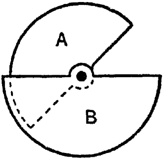


Fig. 46.

A variable condenser, as the name suggests, is one the capacity of which can be readily altered, and these are extensively used in wireless. The most common type employs an air dielectric, the variable capacity being obtained by rotating one set of metal plates into and out of another fixed set of metal plates, the rotating plates being all metallically connected together and forming one coating of the condenser, the fixed plates being similarly connected and forming the other coating of the condenser.

In one type both sets of plates are semicircular in shape to obtain a uniform increase or decrease *of capacity* as the moving plates are rotated into or out of the fixed plates. It should be noted that the capacity is greatest when the moving plates are completely inside the fixed plates, and least when the moving plates are outside the fixed. The principle will be gathered from the plan of the plates given in Fig. 46.

Another type of variable condenser is known as the **square law condenser**, and it has replaced the ordinary form referred to above. It works on exactly the same principle and looks very similar, but the plates are so shaped that the rotation of the moving plates is proportional to the *wave length* of the wireless wave which is being received.

In other words if we were listening to a broadcasting station sending out a wave length of 250 metres and the variable condenser was at 10°, and if we wished to get another station transmitting a 500 metre wave, it would only be necessary to rotate the condenser to 20° (we are making certain assumptions here which will be understood later). Fig. 47 shows roughly the general "cam" shape of the moving plates of a square law condenser.

With the present scheme of broadcasting a slightly modified form of the above square law condenser is best in which rotation is proportional to *frequency*.

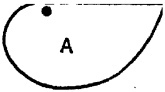


Fig. 47.

Fig. 48 shows a type of modern variable condenser used in receiving sets.

The aerials used in both transmission and reception of broadcasting are condensers, the wire forming the one coating, the earth and earth-joined bodies the other coating, the air between being the dielectric.

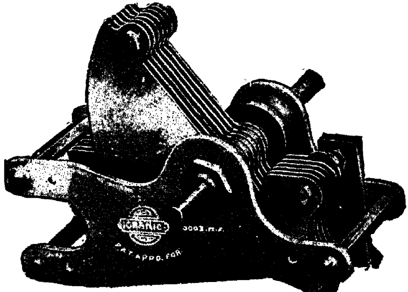


Fig. 48.

7. **Inductance and Inductance Coils.**—We mentioned at the beginning of Art. 6 that two properties were essential in a wireless installation whether for sending and receiving sound or vision: one of these is *capacity* which is associated with condensers, and the other is termed **inductance**, a property to

which reference was really made in Art. 7 of Chapter I. Before proceeding to deal with inductance, however, we must say just a little about *magnetism*.

Most people know what a magnet is: it is a piece of iron or steel (generally horse-shoe shaped or in the form of a bar) which attracts other pieces of iron and steel, and which, if suspended, comes to rest in a definite direction which is nearly north and south, the one end always pointing towards the north and the other end towards the south. The end which points towards the north is called the *north pole* of the magnet and the end which points towards the south is called the *south pole* of the magnet.

Incidentally *permanent* magnets are made of very hard steel, but what are called *electromagnets* which are used in several electrical appliances, and which are required to quickly become magnetised and to quickly lose their magnetic properties, are made of soft iron.

Now if the north pole of a second magnet be brought near the north pole of a suspended magnet there will be repulsion between them, but if the north pole be brought near the south pole of the suspended magnet there will be attraction. Similarly two south poles repel each other. Thus we have the important law that "Like poles repel each other and unlike poles attract each other."

The space outside a magnet throughout which its influence is felt is called the **magnetic field** of the magnet. Now we cannot get a north pole by itself or a south pole by itself as we can get positive and negative charges by themselves, for a (perfect) magnet always has two poles, one north the other south. Let us imagine, however, that we have got a single north pole. If this north pole be placed at any point in a magnetic field it will be urged by a definite force in a definite direction, and this direction is indicated by what is called a **line of magnetic force** passing through the point in question.

Fig. 49 shows the lines of magnetic force in the case of two unlike poles facing each other, and Fig. 50 shows the lines in the case of two like poles. You can easily show the direction of these lines by placing the magnets under a sheet of cardboard and sprinkling iron filings out of a muslin bag on to

the cardboard: the filings will arrange themselves along the lines of magnetic force.

There is just one more point we need mention in passing. These magnetic fields and lines of magnetic force and those electric fields and lines of electric force mentioned on page 7 are really *in the aether*, not in the air. Two electrified bodies or two magnet poles attract or repel each other even if they are in a vacuum, *i.e.* in so called empty space. Similarly we can get magnetic force lines with suitable apparatus even in a chamber where there is no air, only aether.

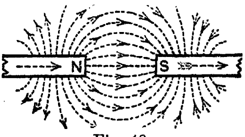


Fig. 49.

Now there is a very important connection between electricity and magnetism, and that is that *whenever an electric current flows along a wire a magnetic field is set up on all sides of it, the lines of magnetic force forming circles round about the wire*, and when the current stops the magnetic field disappears.

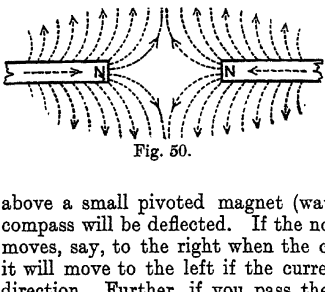


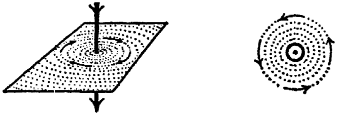
Fig. 50.

You can show that there is a magnetic field outside the wire by holding the wire above a small pivoted magnet (watch-chain compass): the compass will be deflected. If the north pole of the compass moves, say, to the right when the current is going one way, it will move to the left if the current flows in the opposite direction. Further, if you pass the wire vertically through a hole in a sheet of cardboard (Fig. 51), you can show the circular lines of force by means of iron filings.

Finally, if you take an insulated copper wire (*i.e.* a copper wire covered with some insulating material) and coil it round a bar of soft iron as shown in Fig. 52, then on starting a current in the wire the bar immediately becomes a powerful

magnet, one end being a north pole and the other end a south pole: when the current stops the bar becomes demagnetised: if the current goes in the opposite direction the bar will again be magnetised, but the polarity will be the other way about. Magnets made by an electric current in this way are called electro-magnets.

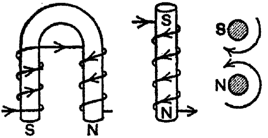
Now in 1831 Faraday showed that if a magnetic field in the vicinity of an electric circuit be changed in any way an electric pressure—and in most cases a current—is set up in the circuit, such pressures and currents only lasting while the change is taking place. Pressures and currents produced in this way are spoken of as **induced pressures** and **induced currents.**



Conventional current "down." Conventional current "up."

Fig. 51.

Thus in Fig. 53 imagine **CD** is a *coil* of wire joined to a battery and **AB** another *coil* joined to a galvanometer which is simply a coil of wire with a pivoted magnet at the centre: the magnet will be deflected if a current passes. **CD** is referred to as the **primary** circuit and **AB** as the **secondary** circuit.



The arrows show the direction of the conventional current.

Fig. 52.

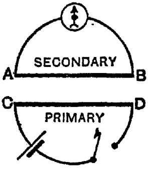


Fig. 53.

Now if a current be started in **CD** in the direction **C** to **D** the galvanometer will be deflected for a moment showing that a momentary current has been induced in **AB** in the direction **B** to **A**, *i.e.* opposite to the primary current. Of

course starting a current in **CD** means that we are suddenly setting up a magnetic field, and some of the lines naturally reach the circuit **AB**. If we stop the current in **CD** we wipe out the magnetic field and the galvanometer will indicate that a momentary induced current is set up in **AB** in the direction **A** to **B**, *i.e.* in the *same* direction as the one which is being cut off.

Similar results happen if the current in **CD** is increased or decreased in strength. Inductive effects between two circuits like the above are spoken of as **mutual induction.**

It is clear that if an alternating current be flowing in the primary **CD**, then since the magnetic field is changing constantly currents will constantly be induced first one way then the other in the secondary **AB**.

Now if you go back and read Art. 7 of Chapter I. you will see this is just what we told you in that section, only there we did not mention the magnetic field which always accompanies a current and changes when the current changes: we merely said the aether was agitated when the current changed and the disturbance travelled out and agitated in turn the electrons in any conductor in its path.

But a magnetic field and also an electric field are really *in the aether* and a changing electric or magnetic field are therefore a change or disturbance in the aether. There is much more that might be said about this, but for the present it will answer our purpose if you simply realise that the above and Art. 7 of Chapter I. practically amount to the same thing.

Again, we have seen that when we start a current in a circuit this current produces a magnetic field. Now this field reacts upon the current itself by setting up an *opposing* pressure which delays its growth, the result being that it takes time to cause a current to reach its full value in the circuit. Similarly, when the current in a circuit is broken, the field is destroyed, and an induced current in the *same* direction as the one cut off is established. Similar results obviously take place when a current in a conductor increases or decreases in strength. These effects are known as **self-induction.**

You should notice the " oppositeness " of all these inductive effects. When we start or increase a current in a wire we get

an induced *opposing* pressure in the wire itself and an induced *opposite* current in a neighbouring wire. When we stop or decrease a current in a wire we get an induced current in the *same* direction in the wire itself and an induced current in the *same* direction in a neighbouring wire.

When a body is at rest it tends to remain at rest and when it is once in motion it tends to keep moving, and this property is referred to as *inertia*. Now from the preceding it will be clear that self-induction behaves in a circuit like *inertia*, *e.g.* when we try to produce a current in a circuit this self-induction or inertia tends to choke the current back, and when we try to stop the current this self-induction tries to make it keep on.

The general name for the preceding property shown by conductors of electricity, *i.e.* the property of choking back a current which is starting or increasing, and prolonging a current which is stopping or decreasing, is **inductance.** In a straight wire the inductance is small: it is much greater in a coil of many turns, and it is greater still if the coil is wound on iron.

Inductance is measured in terms of a unit called the **henry,** *i.e.* we speak of *an inductance of so many henries.*

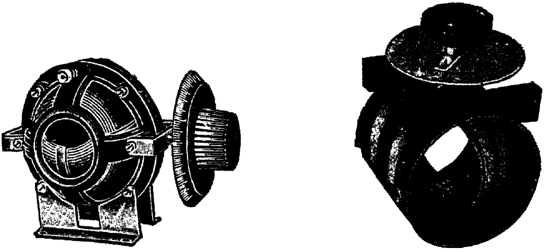


Fig. 54.

There are many different types of inductance coils in use, each having certain features making it specially suited for particular cases. You will learn in Chapter IV. how and why inductance coils are used.

The **variometer** (Fig. 54) consists of an outer fixed coil of insulated wire known as the *stator*, inside which is another coil of insulated wire capable of rotation and known as the *rotor*. One end of the stator wire is connected to one end of the rotor wire, the other end of the stator wire and the other end of the rotor wire being joined to the two terminals of the variometer; the two coils are thus in series. Rotating the inner coil varies the inductance. The coils are usually wound on short cylinders of cardboard or vulcanite.

The **tapped inductance** is shown in principle in Fig. 55. It simply consists of a coil of insulated copper wire, but at intervals tappings are taken from it to studs, connection to the latter being made by means of a rotating switch arm.

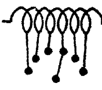


Fig. 55.

The **loose coupler inductance** utilises the principle of mutual induction explained above. It consists of two coils separate from each other, but one capable of sliding inside the other. Frequently the larger or outer coil is also fitted with sliding contacts, and the smaller or inner coil as a tapped inductance, in order to secure further scope for variation of the inductance. The usual method of using such a loose coupler in a receiving set is to join the outer (or primary) coil to the aerial and earth and the inner (or secondary) coil to the detecting circuit: this will be seen, however, later. The more the sliding one is inside the other the bigger is the inductance.

There are various methods of actually winding inductance coils so as to make them best suited for the purpose, but we need not trouble you about these details.

The **plug-in inductance coil** is the form in which the inductance coils are often arranged in practice. The ends of the coil are brought to a plug and socket mounted in a piece of ebonite attached to the coil: the receiving set is fitted with a corresponding plug and socket so that the coil can be " plugged in."

Fig. 56 shows the general appearance of the Lewcos X plug-in coil which is also provided with three extra tappings, and Fig. 57 shows a simple coil holder. A variable coupling using the property of mutual induction can be used with two plug-in coils and the coil holder shown in Fig. 58: the holder

carries two plug-in coils—a primary and a secondary—and one is pivoted as indicated so that the distance between them can be varied.

Fig. 56.

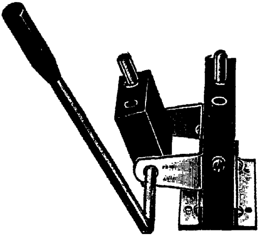


Fig. 58.

Coils are numbered by the makers to indicate their suitability for particular wave lengths: this, however, is dealt with in Chapter VII.

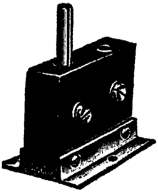


Fig. 57.

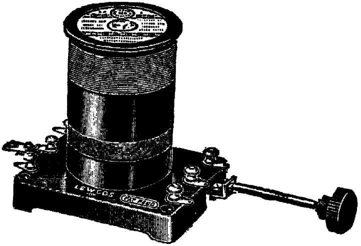


Fig. 59.

Nowadays what are called *shielded coils* are largely used *i.e.* the coils are surrounded by a metal box or case; and coils

with special tappings are also used for special purposes. Thus the Lewcos D.W.A. coil is shown in Fig. 59, and Fig. 60 gives the principle of the various internal arrangements and tappings, when the coil is used in an aerial circuit. The rod shown is a switching device: if the rod be pushed in the coil is suitable for receiving waves of 1,000–2,000 metres, and if pulled out it is suitable for receiving the medium waves of 235–550 metres. There are other applications of the coil which you will come across later. Do not worry, however, about Fig. 60 just now: you will understand the why and the wherefore of it when you come to the chapter on receiving circuits.

8. Electric Motors.—You know that an **electric motor** is a device which when supplied with current from a battery or from the electric mains begins to rotate, and in rotating it can be made to drive machinery and the like. In television small motors are used both at the sending end and in the "televisor" at the receiving end. The whole question of motors and motor-action is rather difficult, and a full knowledge of them is not required for television purposes: you simply buy one and follow the maker's instructions. We will, however, give you an elementary idea about them in as few words as possible—that is all you want.

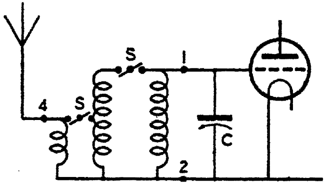


Fig. 60.

In the early days of electricity it was found that if a wire were suitably suspended in a magnetic field in between the north and south poles of a magnet and then a current of electricity were passed in the wire, the wire moved. Thus in Fig. 61 if the "conventional" current flowed down the wire (*i.e.* the true electronic current flowed up the wire) by joining **A** to the positive and **B** to the negative pole of a

battery, the wire would tend to move in the direction "out of the paper, *i.e.* towards the reader": if the same current flowed up the wire it would tend to move in the direction "into the paper."

There is a handy rule which enables you to tell which way the wire tends to move. *Hold the thumb and the first two fingers of the left hand mutually at right angles to each other. Point the fore-finger in the direction of the magnetic lines of force from N to S* (Fore-Force), *and point the middle finger in the direction of the "conventional" current in the wire: the thumb will be pointing in the direction of motion of the wire* (*thu*Mb-M*otion*). Try this rule on Fig. 61, and verify what we have just told you.

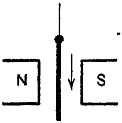


Fig. 61.

Now imagine we have a ring or cylinder of iron wound uniformly with a coil of insulated copper wire, the beginning and end of the coil being soldered together so that the coil is endless (Fig. 62). Imagine this supported on an axle through its centre so that it can rotate between the poles **N** and **S** of a magnet. This coil and its iron core (*i.e.* the moving parts) are called the *armature* of the motor, and the fixed magnet or magnets is referred to as the *field magnets.* Imagine further that each outside wire has a small piece of insulation taken off it, and that two pieces of springy copper **A** and **B** or two pieces of carbon (called brushes) are so

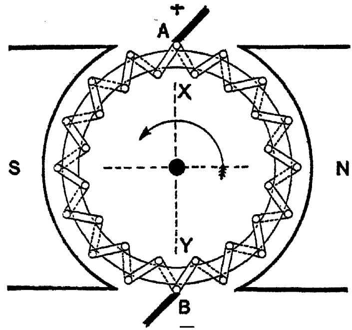


Fig. 62.

placed that they just graze the bare parts when the coil and its iron core rotate.

Now suppose **A** is joined to the positive pole and **B** to the negative pole of a battery. The (conventional) current from the battery divides at **A**, half going down the coils on the left to **B** and half going down the coils on the right to **B**. Taking the *outside* coils on the left it will be seen that the current flows in them from back to front, *i.e.* towards the reader, and if you apply the above rule you will find that these tend to move *downwards*. Taking the *outside* coils on the right it will be seen that the current flows in them from front to back, and if you apply the rule you will find these tend to move *upwards*. Hence continuous rotation of the armature takes place in a counterclockwise direction and this rotation can be made to drive other apparatus or machinery.

In very small toy motors the magnet **NS** may be a permanent magnet, but in most cases the fields are made of soft iron fitted with coils of wire, and either the whole of the current which is fed to the armature or a part of it is passed round the field coils thus magnetising the fields, *i.e.* making them electromagnets. If all the armature current passes round the fields to magnetise them the motor is called a *series motor*: if a part of the armature current is shunted off to magnetise the fields it is called a *shunt motor*. Fig. 63 shows in diagrammatic form the idea of a series and a shunt wound motor.

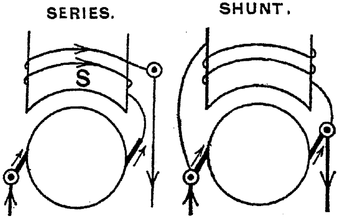


Fig. 63.

Of course, in practice the brushes **A** and **B** would not make contact with the actual armature coils: they make contact with a *commutator* as it is called, and this commutator leads the current to the coils. However, we need not go into the details of the cummutator here.

Broadly speaking motors may be divided into two classes, viz. those which are supplied with alternating current and those supplied with continuous current, and the above explanation applies to the latter type. In television direct current motors are largely used, and they are usually shunt-wound motors, for in television constant speed is absolutely necessary, as you will see later, and shunt-wound motors have more or less this property of constant speed.

Nevertheless there are arrangements for controlling the speed so as to get it to the right value and to keep it quite steady. The field coils have a variable resistance in series with them (Fig. 64): increasing this resistance increases the speed, and decreasing this resistance decreases the speed. Moreover, television receiving motors are fitted with another arrangement, which ensures that the motor at the receiver runs exactly in step with the motor at the transmitter. This will be explained later.

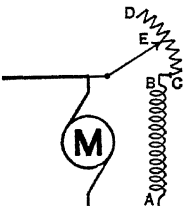


Fig. 64.

For receiving television a motor of from $\frac{1}{16}$ to $\frac{1}{8}$ horse-power is suitable, and it should be able to run up to from 800 to 1,000 revolutions per minute. About 750 revolutions per minute is really required for television as at present broadcast by the B.B.C., but it is better to have a reserve speed. Suitable motors can be purchased either to run off the mains or to run from accumulator batteries. The Vidal Engineering Co. turn out several suitable small motors to be run by accumulators giving from 6 to 12 volts pressure and about 2 to 3 amperes of current, whilst the General Electric Co. market some excellent types to run off the mains at from 100 to 250 volts.

The construction and general principle of the alternating current motor differ from those of the direct or continuous current motor, but it is unnecessary to go into these points here. Incidentally, the motor known as the "Universal" can be run off either direct or alternating current mains.

9. Scanning Discs.—The **scanning disc** is an appliance which is used both at the sending end and in the receivers in television, and although it is a very simple looking piece of apparatus it is one which must be constructed with the greatest care and be extremely accurate as you will readily understand when reading Chapter IV.

Briefly the scanning disc is a circular sheet of metal provided with a number of small square holes arranged at equal distances along, not a circle, but a curve which is a well-known *spiral* of one complete turn as shown in Fig. 65 (each hole, you will notice, is a little nearer to the centre than the one in front of it). The disc must be rigid and not too thick or too heavy, and 22 gauge aluminium or the thin sheet steel known as "taggart" are suitable materials.

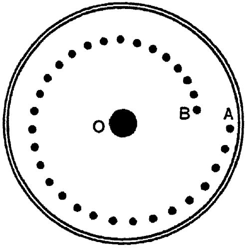


Fig. 65.

The Baird Television Company use 30 holes in their discs and for reasons which will be mentioned later, the first three holes and the last three holes in the spiral are rectangular: in America 60 holes are mainly used. The reduction in radius from the beginning to the end of the spiral, *i.e.* the difference between the radii **OA** and **OB**, is called the *pitch*, and the side of each of the square holes (and the short side of the rectangular holes) is nearly $\frac{1}{30}$ of the pitch. The pitch determines the width of the picture, and the height of the picture depends upon the distance between one hole and its neighbouring hole.

Thus the sizes of the disc, spiral, and holes, affect the size of the picture, as will be understood later. A disc which has given good results on recent television broadcasts was made of aluminium sheet and was $27\frac{1}{2}$ inches in diameter, with 30 holes each of 1 mm. side, the first and outermost hole starting at a radius of 13 inches, *i.e.* $\frac{3}{4}$ inch from the edge.

A scanning disc is mounted at its centre on the axle of a motor and rotates with the motor armature, the speed in the

Baird system being 750 revolutions per minute. At the sending end the object to be televised is at one side of the disc and a beam of light from the other side of the disc is projected through the holes on to the object as the disc rotates, and in this way the beam or spot-light is made to "scan" the object somewhat after the style referred to in Art. 11 of Chapter II. At the receiving end in the televisor the disc is rotated in between the observer and the neon lamp. All this, however, will be explained presently.

The receiving disc need not be the same size as the disc at the sending end, but it must have the same number of holes and must rotate at the same speed: it must also be "in step" with the disc at the sending end, as will be seen later. Discs are painted a dead black so that they do not reflect any light.

10. Head-Phones, Loud-Speakers, and Microphones.—The "Bell magneto telephone," as it is called, was originally used both as a sound **receiver** which, in the form of headphones and loud speakers, is used with radio receivers to-day, and as a sound **transmitter** corresponding to the transmitter known as a *microphone*, which is now used at broadcasting stations. We will consider the action of the Bell telephone in this double sense.

A section through the instrument is shown in Fig. 66. Here

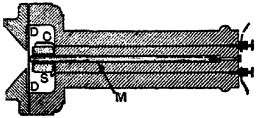


Fig. 66.

M is a permanent magnet carrying at one end a piece of soft iron **S**. This forms the core for a coil **C** which has leads to the two terminals of the instrument. In front of **S** is fixed a very thin soft iron disc **DD**. The main body of the instrument is of ebonite.

The action is as follows: When a person speaks into the instrument the sound waves cause the disc to vibrate, and as it moves to and from the soft iron core the distribution of the lines of force in the vicinity of the coil is altered. A current is, therefore, induced in **C**, and this current changes according

to the rate at which the number of lines of force passing through **C** changes, *i.e.* according to the vibrations of the disc and therefore according to the words spoken. At the far end of the circuit is a similar instrument to act as a receiver, the terminals of which are directly connected to those at the transmitter, so that as the currents generated in **C** vary with the sound, so also do those received at the distant receiver.

The reverse operation now takes place at the receiver. The current in its coils varying, the field in the neighbourhood varies, and the soft iron piece of the receiver attracts with varying strengths the vibrating disc immediately in front of it. Thus the disc of the receiver copies the movements of the disc of the transmitter, and these movements of the receiving disc being transferred to the air, the sound also is reproduced.

From the above it will be seen that two of these instruments without any battery can be used as a simple telephone circuit.

In modern practice the Bell telephone is used only as a receiver (*e.g.* the head-phones) and Fig. 67 depicts the construction of one present type of instrument. **M** is the permanent cobalt-steel magnet; as a rule it is in the form of a ring and is fitted with soft iron pole pieces **P** on which the coils **C** are wound. **D** is a stalloy disc. The containing case is of ebonite or some special composition. The wires leading from the coils to the terminals are not shown in the figure.

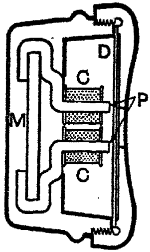


Fig. 67.

Some "loud speakers" work on the same principle (they are designed to produce a big volume of sound) and need not be described here.

The principle of the modern microphone transmitter is as follows: If we produce sound waves near a loose electrical contact, particularly in the case of one or more sticks of carbon supported lightly by two fixed blocks of carbon, the vibrations cause the resistance of the points of contact to vary enormously, and thus a battery in series with the loose carbons will send a varying current through the circuit as long as the sound

vibrations continue; this varying current passing through a telephone receiver will actuate it in the way we have already described, so that the sound is reproduced. Such an arrangement is shown diagrammatically in Fig. 68, where **C** is a rod of carbon and **A** and **B** two carbon blocks.

Notice particularly that when we speak into it we vary the resistance at the top and bottom of **C**, thus varying the current given by the battery, and this varying current works the telephone receiver **T**.

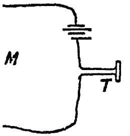


Fig. 68.

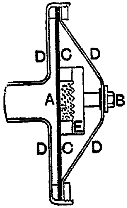


Fig. 69.

Fig. 69 shows the details of a modern transmitter. A number of granules of carbon (**A**) are enclosed in a chamber, the back and front of which are carbon discs. The back disc **E** is joined to the terminal **B**: the front disc is attached to the diaphragm **C**, which is held by its rim in the metal case **D**; **D** is insulated from the terminal **B**. The circuit is connected to **B** and **D**, the battery and receiver being included in the circuit. The battery can, therefore, send a current to **B**, to **E**, through the carbon granules **A** (between which a large number of loose contacts exist), and hence to **C**, to **D**, and back to the circuit and battery.

When we speak into the microphone the diaphragm vibrates according to the sound waves, *i.e.* the words spoken. This produces compressions and decompressions of the granules. When the granules are pressed together the resistance is made less, and when they are slacked the resistance becomes greater. Thus the resistance varies and the current given by the battery varies according to the words spoken, and the

telephone receiver in the circuit reproduces the words. A funnel-shaped mouth piece is usually fixed to the opening in front to concentrate the sound waves on the diaphragm.

In practice the microphone is not directly connected to the receiver so that the microphone, battery, and receiver form one circuit as in Fig. 68. The microphone is really connected through the battery to a primary coil **P**, and a secondary coil **S** is joined to the receiver. This is shown in principle in Fig. 70. The current variations in the primary circuit cause, by induction, corresponding current variations in the secondary circuit.

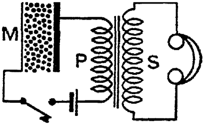


Fig. 70.

The **Reisz microphone** employs a thin layer of powdered carbon spread on a slab of marble and covered by a rubber sheet which takes the place of the diaphragm above. It works on the same principle, but does not tend to strengthen some notes at the expense of others as the granule instrument does.

The **magnetophone** is another type of microphone working on a different principle. It consists of a small coil of wire on the back of a freely moving plate. The coil is in the magnetic field between the poles of a magnet. The sound waves cause the plate and coil to move, and varying currents are induced in the coil. This is largely used in present-day broadcasting. In all cases you will note that we get a varying current depending on the words spoken: what is done with this varying current you will see in the next chapter.

CHAPTER IV.

TRANSMITTING AND RECEIVING TELEVISION.

1. Introduction.—In sound broadcasting or "wireless" as we are now accustomed to briefly call it, you *hear* the voice of the person although he may be hundreds of miles away, with no apparent connection between the two of you, but you know the sound has not travelled to you direct as "sound." In vision broadcasting or "television" by wireless you *see* the person but you know that the light has not travelled direct from him to you as "light." As a matter of fact the sound in the first case and the light in the second case are changed so to speak into corresponding electrical effects at the transmitting station, and then these electrical effects are, as it were, changed back again into sound and light respectively at the receiving end. You will see how this is done presently.

Now there is a distinct connection or similarity between sound broadcasting from, say, the broadcasting studio to the *listener*, and television broadcasting from the studio to the *observer*. Except for a few appliances the two are almost identical, and the latest one—television—cannot be explained to a beginner so that he may *really* understand it without some explanation of the other: in fact "wireless" transmitters "wireless" receivers, "wireless" waves, and "wireless" accessories are all used in television. We will therefore first briefly explain the general principles of broadcasting and reception, and then you will be better able to understand the modifications for television broadcasting and reception.

Of course, as in the case of sound, television can be sent by "land-line" as well as by "wireless," but the latter is the case with which we are mainly concerned.

2. The General Idea of Radio Communication.—We have seen that if a rapidly alternating current is kept flowing in a wire, then since it is constantly increasing and decreasing and

reversing, the aether will be in a constant regular or "periodic" condition of disturbance, which will be constantly travelling out, and a corresponding rapid alternating current will flow in any conductor in the path of the disturbance. This, as we pointed out in Art. 7 of Chapter I. is what is occurring in all radio communication: a high frequency oscillatory current is caused to flow in the transmitting aerial, "aether waves" pass out, travelling through the aether at a speed of about 186,000 miles per second, and when these reach the receiving aerial high frequency oscillatory currents are set up in it corresponding to those at the sending end.

You know that if the prongs of a tuning fork be put in vibration, *i.e.* given a regular to and from movement, a **sound wave,** as it is called, is set up in the air which can be detected by the ear. The air in the vicinity of the vibrating body executes a slight to and fro movement in step with it; this movement is communicated to the air in front, and so on, until finally the vibratory motion of the air reaches the drum of the ear, which responds and the sound is heard.

An **oscillation** is a single swing of the vibrating fork from one extreme position to the other. A **vibration** is a double swing—a wiggle-waggle—a "to and fro" movement. The **wave length** is the distance the wave travels during one complete vibration. The **frequency** is the number of complete vibrations in one second. Hence you will see that the **velocity** of the sound wave, *i.e.* the distance it travels in one second, is evidently given by the expression—

Velocity = (Wave Length) multipled by (Frequency).

Now the velocity of sound waves in air is practically constant and equal to about 1,120 feet per second; hence it follows that *the faster the fork vibrates*, i.e. *the higher the frequency*, *the shorter will be the wave length*, and conversely, *the lower the frequency the longer will be the wave length*, for in each case the two multiplied together is 1,120. Thus if the frequency be 560 the wave length will be 2 feet, but if the frequency be only 280 the wave length will be 4 feet. The **periodic time** is the time taken for one complete vibration.

Remember that these sound waves are *waves in the air*: if the air between the fork and your ear were removed you

would not hear a sound although the fork might still be vibrating. Sound waves have nothing whatever to do with the aether, and we will remind you again that the waves used in wireless and television are *not* waves in the air.

Suppose you are sitting on a swing which is going to and fro but that the swings are not big enough to satisfy you. Suppose, however, that just when you start to go forward someone gives you a forward push: you will swing further. Suppose that the next time you are going forward you get another push: you swing further again, and so on. In other words, if the pushes are given at the right time, *i.e.* a forward push every time the swing goes forward, you will get a big swing; but if a push comes when you are moving back, your swinging will soon be stopped.

Now let us go back to our sound waves. If you uncover the strings of a piano and sound a tuning fork near them, you will notice that several of the strings are affected by the waves from the fork, but you will find that that particular string which has the same vibration frequency as the fork will be affected most, and it may be set so strongly in vibration that it gives out the same note as the fork.

This is similar to the swing and pushes. The first wave hits the piano string forward say: the string comes back, and then just when it starts forward the second time, the second wave from the fork just reaches it and hits it forward again, and so on; thus the vibrations of this string are increased. Another string that has not got the same frequency as the fork is hit forward by a later wave when it is moving back and so, like the swing, it soon pulls up.

The above is an example of what is called **resonance**: the two vibrating bodies which have the same frequency are said to be **in resonance** or **in tune** with each other. This idea is very important.

Water is another well known medium in which a wave motion can be set up. Long waves in water are caused by wind and the gravitational pull of the earth. Imagine, however, that you move a stick gently up and down at the centre of a large pond. In this case genuine water waves will be set up, *i.e.* the particles of water will move up and down, *i.e.*

vibrate, forming in succession " crests " and " troughs," and a wave motion will spread outwards in all directions.

Fig. 71 is an easy way of picturing to our eyes a wave motion such as this. The distance from **B** to **F**, *i.e.* from crest to crest or from **D** to **H**, *i.e.* from trough to trough, represents the wave length. These wave lengths represent the distance the wave travels during one complete vibration.

Now we will get on to the waves used in broadcasting speech and television. When the plates of a charged condenser are connected by a large resistance the discharge consists of a fairly well-behaved flow of electrons from one plate to the other, the charges thus neutralising and the potentials of the plates both becoming zero. If, however, the resistance be below a certain value, the discharge consists, not of a steady flow, but of a number of rapid oscillations or surgings of electricity—*i.e.* electrons—to and fro.

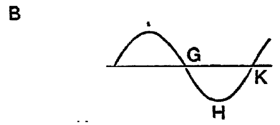


Fig. 71.

The first rush more than neutralises the opposite charge and charges the condenser in the opposite direction; this is followed by a reverse rush which again " overshoots the mark " and charges the condenser in the same way as it was originally, and so on. Each successive oscillation is weaker than the preceding; thus after a number of such surgings the discharge is complete and the potentials of the plates are equalised.

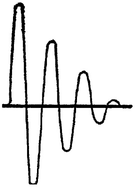


Fig. 72.

Such a surging of electricity to and fro, which surges get gradually weaker and finally die out, may be pictured to the eye in the way shown in Fig. 72. It should be mentioned that these surgings or oscillations of electricity take place very rapidly, and although they get weaker, the time of each is the same.

As a result of all this very rapid swinging of electrons to

and fro, the aether in the vicinity is thrown into a state of agitation, *i.e.* it is undergoing a regular or periodic change of state due to the regular swinging of the electrons to and fro.

This periodic variation of state is transmitted with a definite velocity throughout the aether; that is, we have a train of waves, called **electric waves** or **electromagnetic waves** which travel outwards through the aether with a definite velocity. This velocity, as we have already told you, has been proved to be 186,000 miles per second or 300,000,000 metres per second, the same as that of light. With suitable apparatus these are the waves used in broadcasting, etc.

Think for a moment what it is we really have in the above circuit. We have a condenser which possesses *capacity*. We have a wire joining the plates which possesses *resistance* and also *inductance*. In wireless the resistance of a circuit is always kept as small as possible. Let us neglect the resistance then and say that the two main things we have got are **inductance** and **capacity**. Of course inductance is only very small in a straight wire, but it is much bigger in a coil of wire, and in wireless, coils are used.

Now mathematical people can prove "with no possible doubt whatever" that the frequency of the vibrations of the electrons in this discharging condenser depends on the inductance and the capacity. *The bigger the inductance and the bigger the capacity the slower are the oscillations*, i.e. *the less the frequency*. And, of course, since the less the frequency the bigger the wave length: another way of putting this is that *the bigger the inductance and the bigger the capacity the bigger is the wave length* of the aether waves that are sent out.

If you seriously think about the matter for a moment, you will see that the above is bound to be the case. Inductance is noted for its "opposition": if the electrons start to go one way, inductance tries to stop them, if they decide to go the other way inductance again tries to stop them, if they are moving and want to stop, inductance tries to make them keep on: whenever the little electrons want to do something fresh inductance says "don't do it." The result is that if electrons are started swinging to and fro in a circuit, inductance

opposes them, slows them up, and therefore the frequency is reduced, and of course the wave length increased.

Similarly, a condenser is greedy: it seizes electrons and, so to speak, stores them up, giving them out only when it is positively compelled to do so: this again slows down the swings of the electrons, *i.e.* reduces the frequency and increases the wave length. Remember then that you can reduce the frequency and increase the length of the waves going out by using a larger inductance (more turns of wire in the coil), and by using a larger capacity (bigger condenser).

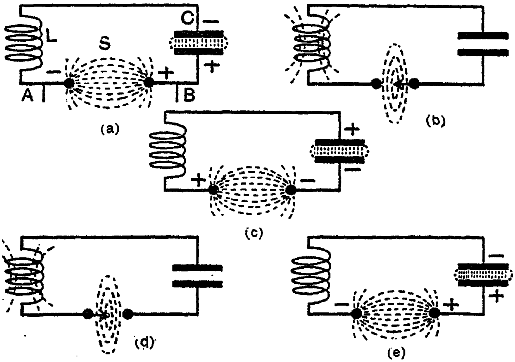


Fig. 73.

In the oscillating circuit we have been dealing with, we started off with a condenser fully charged and we joined the plates by a wire or coil thus getting oscillations of electrons and a train of waves: but in a short time the condenser is discharged and the waves stop. If we want another train of waves we can do it by disconnecting the wire, charging up the condenser again, then putting on the wire, and so on. This is not a practical method, and it gives very poor waves.

Look however at Fig. 73, which shows an arrangement actually used in wireless. Here **C** is the condenser (capacity)

and **L** is the coil (inductance), and the two wires **A** and **B** go to a battery or other source of electricity for charging the circuit. Note, however, that there is a gap **S** (it is referred to as the **spark gap**).

When you switch on the battery the condenser is charged until the potential difference across the gap is big enough to overcome the resistance of the air in the gap: then a spark passes. This spark is, of course, oscillatory, *i.e.* it is only our little friends the electrons rushing backwards and forwards due to the condenser discharging just as in the previous cases, and of course waves pass out. When the oscillations have died down however, and the waves ceased, the battery again charges up the condenser and the action is repeated. Thus if you have a key in the battery circuit joined to **A** and **B** you will get a series of waves going out as long as the key is kept closed. Such a succession of waves might be represented to the eye as shown in Fig. 74.

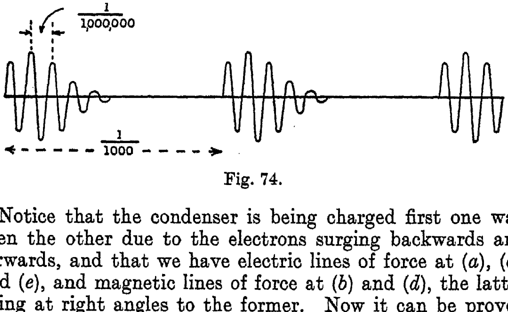


Fig. 74.

Notice that the condenser is being charged first one way then the other due to the electrons surging backwards and forwards, and that we have electric lines of force at (*a*), (*c*), and (*e*), and magnetic lines of force at (*b*) and (*d*), the latter being at right angles to the former. Now it can be proved mathematically that if we have in the same space—the aether—a rising and falling magnetic field and a rising and falling electric field at right angles we are *bound to have* a wave motion travelling out through the aether in a direction at right angles to both the electric and magnetic forces.

The above "closed oscillatory circuit," as it is called, does not send out a lot of energy in the form of aether waves,

whereas we want as much thrown out as possible. If, however, the condenser plates be opened out, as it were, thus forming an "open oscillatory circuit," we readily get energy passed out in the form of waves, and this is done in practice.

Fig. 75 shows the idea of "opening out" the condenser plates **A** and **B**, and it also shows the electric lines (dotted) and magnetic lines at right angles. You can see that this arrangement lets the waves get out into space much better than if the condenser plates are close together. We have not put a spark gap or shown the charging arrangement in Fig. 75 because at present we merely want you to get the general idea.

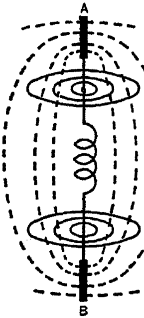


Fig. 75.

Yet another method is to arrange for the closed oscillatory circuit of Fig. 73 to act inductively on an open circuit up against it.

Hertz, in 1888, used a method of sending out electric waves on the lines indicated above. His transmitter (Fig. 76) consisted of two metal plates connected to a spark gap and to a coil, the capacity between the two plates and the inductance of the connection between them forming the necessary capacity and inductance for the oscillatory circuit. The coil on the left was connected to a battery, a sending key, and a vibrating piece which kept starting and stopping the current as long as the key was closed—just as the vibrating piece in an electric bell keeps making and breaking the current as long as the bell push is closed. Thus as long as the sending key is closed the vibrating piece keeps starting and stopping the current in the coil on the left, inducted currents are therefore constantly being set up in the coil on the right, sparks pass quickly at the gap and electric waves pass out into space.

About 1895 Marconi discovered that if one of the spark gap terminals in Hertz's transmitter were connected to a plate buried in the ground, the surface of the earth could be used as one plate of the condenser; and also that the higher the other plate was above the ground the greater was the distance over which he could transmit the waves. He found that an actual upper plate was unnecessary, and that a vertical wire (the **aerial**) supported by a kite or masts gave similar results. Horizontal aerials are, of course, mainly in use now. Fig. 77 gives a general idea of Marconi's arrangement, with a variable inductance in the aerial for tuning purposes.

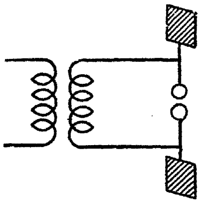


Fig. 76.

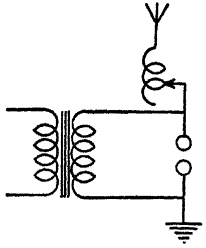


Fig. 77.

At the receiving station the waves from the transmitting station fell upon a similar aerial and set up electrical oscillations in it of the same frequency as those at the transmitting station, the receiving aerial being tuned to suit the arriving waves by variable inductances and capacities.

You will understand how tuning works. If a condenser and an inductance coil be joined to the receiving aerial they really become part of that aerial. If the coil be made bigger or the condenser bigger the frequency of any oscillations set up in the aerial will be reduced, and if they are made less the frequency will be increased. By altering the condenser and inductance, therefore, we can so arrange matters that when a wave comes up and starts an oscillation in the aerial that surge will rush along the aerial and come back just in time to

be caught by the next wave reaching the aerial—just in fact like the swing and the pushes delivered at the right moment.

Always bear in mind that increasing the inductance or increasing the capacity will tune the aerial to receive a longer wave and decreasing them will tune it to suit a shorter wave. Remember, too, that the transmitting circuit must be tuned to the required wave length to be sent out, and the receiving circuit must be tuned to the waves to be received.

In the spark system which we have been considering, high frequency currents, *i.e.* oscillating currents, are being produced while the spark is passing: they gradually die down and then when another spark passes they flow again and gradually die down, and so on. Hence there are times when electric waves are being sent out by the aerial and times when no waves are being sent out, although the sending key may be depressed all the time. Fig. 44 will make this clear.

The number of times the spark occurs in one second is called the **spark frequency** or **note frequency**, whilst the number of complete vibrations of the high frequency current in one second is often referred to as the **wireless frequency**; this latter is the frequency mentioned in the preceding pages. The time between the successive crests of the high frequency or oscillatory currents is very short, of the order $\frac{1}{1000000}$ of a second (Fig. 44). On the other hand the time between the sparks is longer, of the order $\frac{1}{1000}$ second.

Now in addition to the tuned receiving aerial we must have some arrangement for indicating that the waves have arrived and for giving us intelligible signals, *e.g.* a telephone. But before a telephone can be made to operate something has to be done to these high frequency oscillating electric currents in the receiving aerial, and that is where the crystal or the valve become necessary in your wireless receiver.

If you were standing upright and someone gave you a push on the chest you would go backward, but if someone immediately pushed you on the back you would go forward. If you can picture yourself being equally pushed backwards and forwards at the rate of two million pushes per second you would simply remain standing upright. If, however, the pushes on your back were to stop, down you would go at once.

Now similarly, the oscillating currents—currents first one way and then the other—set up in the receiving aerial are of too high a frequency (a million and more per second) to work say a telephone directly, for the moving disc would not have time to move between one rush and the next one in the opposite direction. If, however, we wipe out, in some way, the currents in one direction then the currents in the other direction will work the instrument. In other words, what we want to do is to produce in the recording part of the receiving circuit—say the telephones—" one direction " currents which must of course vary according to the trains of waves arriving at the aerial. This is what the crystal and the valve do.

The action of a crystal, for example, depends on the fact that current can only pass through it in a certain direction, so that it changes an oscillatory current into a one direction current by stopping the flow in one direction. Fig. 78 shows a method of using a crystal as a detector or **rectifier**, telephones being used as a receiver. The oscillations in the aerial due to the arriving waves tend to set up oscillatory currents in the telephone circuit, but the crystal refuses the current in one direction, so that a one direction current flows each time a group of oscillations is set up in the aerial, *i.e.* each time a spark passes at the transmitter. The note heard in the telephones is therefore *of the same frequency as that of the sparks* at the transmitter, and it starts and stops when the train of sparks starts and stops, *i.e.* when the sender closes and opens the sending key.

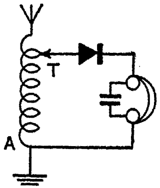


Fig. 78.

You will better understand this **rectifying action** and the resulting effect on the telephones if you look at Fig. 79, which shows the application of the rectifier to the incoming oscillations. The rectifier may be regarded as wiping out all the alternations or half puffs, say, below the centre line and allowing only the half puffs above the line to pass. These half puffs or rectified currents which, although varying in strength, flow only in one direction, pass through the telephones.

Since the telephones are quite unable to respond to the separate high frequency oscillations (which only occupy say $\frac{1}{1000000}$ second) of Fig. 79(*a*), they will still be unable to respond to the separate puffs of the rectified current of Fig. 79 (*b*), but these separate puffs may be looked upon as collected together to form a slowly varying one direction current as indicated in the lower part of Fig. 79, and to this the telephones respond.

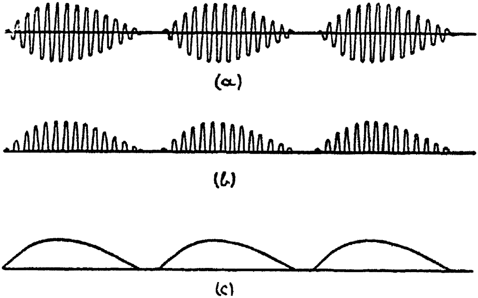


Fig. 79.

Using the numerical value in Fig. 74, we have a rush of current through the telephones every $\frac{1}{1000}$ second, which tends to attract the iron disc as it rises and to allow the iron disc to go back as it falls. The telephones can easily respond to this frequency, so that they send out sound waves at a frequency, which is well within the range of the human ear. Thus the sound actually heard in the telephones has a frequency equal to the spark frequency of the transmitter.

Valves are also used as detectors or rectifiers in a somewhat similar way to the crystal as will be seen presently, but one great advantage of the valve is this. With the crystal the current which works the telephones is picked up directly from the aerial and, of course, it is only weak. With the valve the weak aerial currents cause another much stronger current from a battery (H.T. battery) to work the telephones, this strong unidirectional current varying however in strength in

the same way as the aerial oscillations are varying. Valve detectors or rectifiers are mainly used in wireless sets now and always in television and we will talk about them in Chapter VI.

Now oscillations like those we have been considering which gradually weaken and die out are called *damped oscillations*, and the waves they send out are called **damped waves**, but modern transmitting stations use *undamped oscillations* (which do not gradually decrease and die out), and the waves sent out are similarly **undamped** or **continuous waves.** These are the kind of waves used in broadcasting speech and television. The damped waves from a spark transmitter are all right for telegraphy—the sending of " longs " and " shorts," *i.e.* dashes and dots according to the Morse Code—but they are not suitable for telephony and television.

This simply means that continuous high frequency oscillatory current—produced in various ways with which we need not bother at present—is made to circulate in the transmitting aerial, and this gives rise to undamped waves in the aether which travel out in the way we have already indicated. When these waves meet the receiving aerial, undamped electrical oscillations are induced in it of the same frequency as those at the transmitting station, the receiving aerial being of course tuned to the arriving waves. The detector then picks these up, wipes out, say, the left hand puffs of current, and allows the right hand puffs, *i.e.* a unidirectional current, to pass through the recording instrument.

There is an important point here as to how the telephones respond to these, but we need not trouble about it.

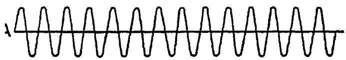


Fig. 80.

Now let us see how the speech and music in our usual sound broadcasting is sent and received.

The undamped high frequeney electrical oscillations in the transmitting aerial produce an undamped wave (like Fig. 80) which is passing out all the time broadcasting is taking place. This wave is called the **carrier wave.**

Joined (in various ways according to the transmitting circuit used) to the transmitting aerial, is a microphone. When the person broadcasting speaks into the microphone the sound waves cause changes in the microphone current, and therefore corresponding variations in the aerial current, so that we have a resulting oscillatory current in the transmitting aerial which varies in strength in a most complicated way according to the words spoken. This again in turn produces a complicated aether wave varying according to the words spoken which, when it reaches the receiving aerial, sets up corresponding complicated electrical oscillations in it, *i.e.* oscillations varying in strength in a complicated way according to the words spoken at the transmitting end.

These complicated oscillations in the receiving aerial pass on to the detector which wipes out the puffs at one side leaving the complicated puffs at the other side to pass through. These latter unidirectional puffs, still complicated according to the words spoken, pass through the telephone or loud speaker, and the words are reproduced.

The essential fact is that the speech of the operator is caused to **modulate** the carrier wave, and the receiving telephone or loud speaker reproduces the sound to which the modulated wave is due.

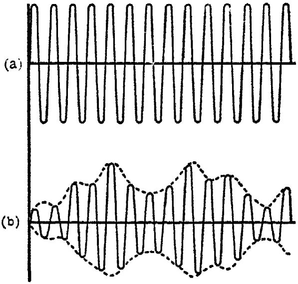
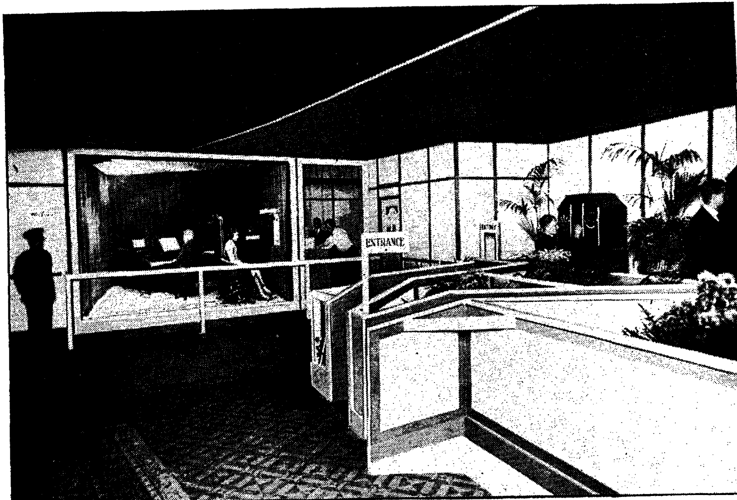


Fig. 81.

Fig. 81 (*a*) depicts a carrier wave and Fig. 81 (*b*) a modulated wave when the operator is speaking into the microphone. Of course, the carrier wave should have very many more oscillations shown in it than are given in the figure.

Now note these points particularly: (1) The high frequency electrical oscillations in the transmitting aerial—the swinging of electrons to and fro at the rate of, say, a million times



From the Left: Studio, Control Room, and on the extreme right "Televisor" receiving the transmissions.

per second—are going on all the time. The carrier wave is rushing along through the aether all the time. The high frequency electrical oscillations set up in your receiving aerial (a million per second) are going on all the time.

(2) When the broadcaster speaks he does not alter the frequency of these oscillations or the wave length of the wave going out, but he does alter the *strength* of the oscillations, *i.e.* the number of electrons taking part in the different swings, and this strength variation depends on the words spoken. It is this strength variation shown by the peculiar irregular shaped curve in Fig. 81 (*b*) which, when one half has been wiped out by the detector, causes the discs of the telephones to waggle in the same way and reproduce the words.

(3) The above explanation is just the same whether in front of the microphone you have Dame Clara Butt with "Abide with Me," or Ambrose's Band with "Give Yourself a Pat on the Back," or the announcer with the interesting news "that there is a deep depression over Iceland." The very rapid oscillations are there all the time in each case, but the *strength variations* are different in the different cases, *i.e.* the "peculiar irregular shaped curve in Fig. 81 (*b*)" is different, and so are the movements of the telephone discs, and so is what you hear.

The carrier wave is necessary in order to carry the slow variations produced by the speech and the music through the aether almost as an aeroplane carries its pilot through the air. If the carrier wave is not there you can bawl as hard as you like into the microphone or sing the sweetest song, and the aether will have none of it; nothing will happen save that the air will carry the sound a short distance.

Incidentally we may mention that the microphone variations produced by the voice are usually strengthened or amplified before being combined with the aerial oscillations, *i.e.* with the oscillations producing the carrier wave. Similarly at the receiving end the aerial oscillations are frequently magnified or amplified before passing on to the detector valve, and the current variations are again magnified or amplified after the detector valve before being passed on to the telephones or loud speaker. These are details which will be dealt with later.

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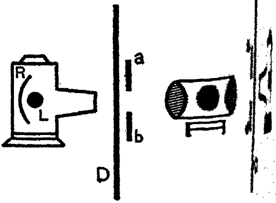

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amplified, then passed to a detector and then the current variations are still further amplified, finally being passed through a neon lamp. The neon lamp, as explained in Chapter III., is thus illuminated, the illumination depending on the current. Hence we get a varying illumination depending on the varying current which again, *when traced right back through the various stages mentioned above to the origin*, depends on the varying light scattered from the person's face in the studio at the sending end. By an arrangement to be explained presently, this varying illumination of the neon builds itself up into the image of the face in the studio.

You will now see the similarity between television and ordinary wireless at the receiving end: the neon lamp changes the varying current from the receiving apparatus into light which reproduces the face in the studio: the telephones or loud speaker change the varying current from the receiving apparatus into sound which reproduces the voice in the studio. The neon corresponds as it were to the loud speaker and the eye of the observer corresponds to the ear of the listener.

We will now examine the whole process and apparatus of television both at the sending end and at the receiving end in detail.

I. At the Sending End.

A glance at Fig. 82 will give you a general idea of the arrangement at the transmitting station, and you should now have no difficulty in understanding exactly what takes place.

We require in the first place a powerful source of light to illuminate the person to be televised. This is shown at **L** and consists of a powerful electric light in a case fitted with a funnel in front through which the light passes out. **R** is a reflector behind the light, and this reflector can be adjusted into various positions to ensure that the light passes exactly as required.

In front of the funnel is the scanning disc **D**, so arranged that when the disc rotates in a vertical plane, *i.e.* about a horizontal axle, each of the 30 holes passes in turn through the beam of light coming out of the funnel of the lamp case. For this to happen, the lamp must, of course, not be opposite

the centre of the disc but off to one side so that the holes, one after the other, *sweep vertically* through the beam of light. The disc is fixed on the horizontal axle of, say, a shunt motor, and of course rotates with the motor armature. This electric motor is not shown in Fig. 82, but you can imagine it standing in line with the centre of the disc and on the left-hand side of it in the figure, *i.e.* on the same side of the disc as the lamp L. The motor and disc run at 750 revolutions per minute or $12\frac{1}{2}$ revolutions per second, and this speed is kept constant by means of a variable resistance in the field circuit of the motor (see Fig. 70): increasing the field resistance, or *rheostat* as it is called, increases the speed, whilst decreasing it decreases the speed.

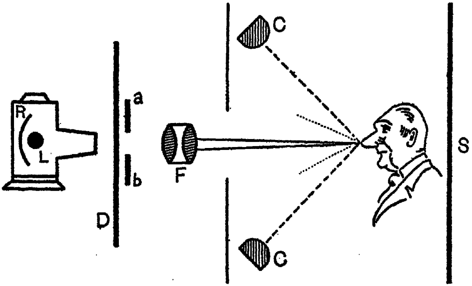


Fig. 82.

On the other side of the disc, *i.e.* on the right hand side of it in the figure is an arrangement consisting of two metal plates *a* and *b*. Both can be raised or lowered thus controlling as it were the vertical height of the light beams which come through the revolving disc holes: it controls, as you will see presently, the vertical height of the " light area " used on the person being televised.

Next to this comes the lens F by which the light is focussed on to the person: this lens is adjusted for the best average " focussing " on the person, and this depends on the distance

between him and the disc. You will know how this lens acts from the details you have read in Chapter II.

Now as a matter of fact we will ask you to forget about this lens for a moment—imagine it is not there. Lenses as you know have the awkward habit of turning images upside down and from left to right, and so on, and as "direction" plays an important part here, as you will see presently, it will only confuse you if we have to take into account the reversing action of the lens. Any slight change in our explanation which the lens will cause we will tell you in due course.

Having settled, then, that you are going to forget about the lens for a moment, we will go back and be a little more definite about the position of the lamp L in relation to the disc. We will take it that the lamp is on the right-hand side of the motor and therefore opposite the right-hand half of the disc face. We will also take it that the disc is revolving *counter-clockwise* (viewed from the left), and therefore that the holes, one after the other, sweep *upwards* through the beam of light.

Now to resume. The next item in our arrangement shown in Fig. 82 is a partition or screen provided with an opening through which the light passes. This entirely shuts off (save for this opening) the apparatus on the left from what we might call the "studio" on the right. At the back of the "studio" is a screen S—generally called the back screen—and it is just in front of this that the person to be televised stands or sits as the case may be. At C is placed the photo-electric cells—really four cells are used—so arranged that light scattered from the person falls upon the cathodes of the cells.

We are now in a position to consider the working of our television transmitting apparatus.

As the disc rotates, each hole comes in turn into the light beam—from the lamp L—and travels upwards through the beam. During this upward journey light passes through the hole, and therefore a "spot-light" due to these narrow beams through the hole sweeps up the back screen. If the disc moved slowly you would be able to see this little square of light moving, as it were, up the screen. If the disc moved very rapidly you would, by "persistance of vision," see a

more or less vertical strip of light on the screen just as in whirling round the glowing end of a match you see a complete circle of light: this we have explained, however, in Chapter II.

When the first hole has passed on the second hole comes into action, and it also traces a more or less vertical strip of light on the screen. As, however, this second hole is a little nearer to the centre of the disc than the first hole, the vertical strip of light it causes to be traced on the screen is a little to the left of the vertical strip due to the first hole. When this hole has passed on the third hole comes into operation, but as it is a little more towards the centre of the disc than the second the vertical strip of light on the screen due to it is a little to the left of the previous one. This action is repeated by each hole in turn, so that by the time the disc has made one revolution, 30 more or less vertical light strips will have been traced on the screen one after the other, somewhat as shown in Fig. 83.

Now imagine that the disc revolves very rapidly so that the whole of the 30 light strips are made in, say, $\frac{1}{16}$ of a second; in other words, that the disc goes round once in $\frac{1}{16}$ second or 960 times per minute. Then, as previously explained, by persistence of vision, we would see not a mere spot of light or a strip of light, but the whole area traced by the beams from the holes—the "light area" as it is called—shown in Fig. 83. In actual practice, as has already been stated, the Baird disc is run at 750 revolutions per minute or 12½ per second, which again is fast enough for persistence of vision to come into play.

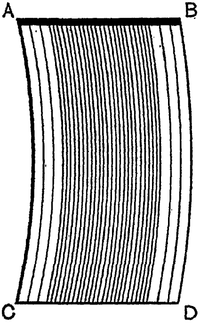


Fig. 83.

It is very important that the holes in the disc should be so arranged that the light strips just touch each other, *i.e.* that the inner edge of the strip traced by the light through the first hole is *just* touching the outer edge of the strip traced by the light through the second hole, and so on. If this is not the case then vertical dark or bright lines will

appear on the "picture" at the receiving end. Thus in Fig. 84 (*a*) the light strips caused by the two holes do not come up against each other, *i.e.* there is a very narrow strip between the two light strips which is not being illuminated at all, and the result would be a dark line on the picture: in Fig. 84 (*b*) the two light strips are overlapping, and there would be a bright line on the picture.

Again it will be noticed that the width of the light area (**ABCD** of Fig. 83) is that due to 30 light strips placed side by side, and therefore is governed by the *pitch* of the disc, *i.e.* the difference between the radii of the first and last holes of the disc. The height of the light area depends upon the distance between one hole and the next, and is also adjusted by the arrangement shown at *ab* in Fig. 82: *a* and *b* are adjusted so that one hole passes out of the light area at the top just *a little before* the next hole comes into it at the bottom. This means that when the spot-light passes off the area at the top there is for a small fraction of a second no light falling on the screen, for the following hole has not yet got into the area. We have indicated this by a black line at the top of Fig. 83. This may seem to you almost a trivial matter at present, but as a matter of fact it is very important, as you will see later.

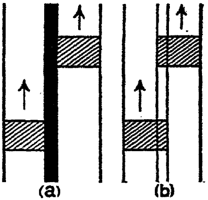


Fig. 84.

Notice also the direction in which the light area is swept out by the travelling spot-lights, for this also is important. The spot begins at **D** in the bottom right-hand corner of Fig. 83, and sweeps upwards to **B**: the next, a little to the left, also sweeps upwards, and so on, the last one of the series sweeping upwards from **C** to **A**: thus the directions of the sweeps or the "scannings" are *upwards and to the left*, i.e. *starting at* **D** *and ending at* **A**. Any other directions of sweep would, of course, act, but this is the method used by the Baird system in this country, and other arrangements in the transmission and reception must be in accordance with this, otherwise things are going to be a little upset.

Baird Television Studio.

Thus (still neglecting the lens F), if the disc ran clockwise the direction of sweep on the screen would not be the standard one above. If the lamp were opposite the other half of the disc face (still neglecting the lens), and the disc moved either clockwise or counter-clockwise, the direction of sweep on the screen would not be the standard one above. Now put in the lens and consider its "reversing" action: this will be good practice for you on the action of a lens. You will find that if the lamp is on the right-hand side of the motor and therefore facing the right-hand half of the disc face (*i.e.* if it is where we have so far supposed it to be), the disc will have to go clockwise, whereas if the lamp is on the other side of the motor and therefore facing the other half of the disc face the disc will have to go counter-clockwise, to produce the sweep on the screen in the standard direction.

However, the important point to remember is how the light area on the screen is swept out, viz. *bottom to top and right to left.*

Now let us imagine the face of a person to be situated in front of the screen in the position of the light area, and that the disc is started rotating: the light spots will sweep over the face in the manner already indicated, and if you were looking you would see the whole face by virtue of that "lag" possessed by the eye, viz. persistence of vision. Remember, in passing, that you "see" the face—or anything—owing to the light it scatters back.

Now instead of your eyes viewing the face consider the photo-electric cell as an eye viewing the face. Unlike your eye the photo-electric cell has no persistence of vision, so that it responds immediately to the light scattered from the small area where the light spot happens to be, and then as the spot moves so the response of the cell changes immediately to the new conditions, *i.e.* according to the light scattered from the new small area where the light spot happens to be. Thus as the face is scanned by the light spot varying amounts of light are scattered from the various parts according to the light and shade—more light from the brow for instance, than from the dark eyebrows—and these varying amounts of light falling on the cathode of the cell cause the cell to give a varying

current—a bigger current with the light from the brow, for instance, than with the light from the dark eye brows. Thus the photo-electric cell picks up the varying scattered light as the light spot sweeps over the face and translates it into an equivalent varying current—a current changing in the same way as the scattered light is changing.

This varying current from the photo-electric cell is very small—only of the order of about $\frac{1}{100000000}$ ampere—and so the current variations of the cell are first magnified or amplified, and then caused to modulate the carrier wave which is passing out from the transmitting aerial. From the television point of view, however, the process need not be considered beyond the stage we have now reached, for the amplifying, and so on, which goes on after this stage are just the usual electrical operations done by the valves and other electrical appliances of the transmitting station, and are the same as in the broadcasting of speech, in "ordinary" wireless. The wireless engineer at the broadcasting station handles the varying currents from the photo-electric cells just as he handles the varying currents from the microphone.

The point to remember is that we have got in the transmitting aerial a high frequency oscillatory current, varying up and down in strength in a complicated way, depending on the "face" televised, and a complicated aether wave passing out from the transmitting aerial—an aether wave which has been modified or modulated, not by the voice of a speaker or singer as in sound broadcasting, but by the light scattered from the various parts of the face in question.

Needless to say the photo-electric cells must be so arranged that no light falls on them except that scattered by the person being televised.

II. At the Receiving End.

Now let us turn to the receiving end. The modulated aether wave arrives, and in the receiving aerial we have a high frequency oscillatory current which varies up and down in strength in a way depending on, say, the particular face in front of the apparatus at the transmitting end. The question now arises, how are we going to change from the varying

current in the receiving aerial into an image of the face in question?

Well, we require two things, viz. first a **wireless receiving set** and secondly a piece of apparatus for changing from electricity to light, and known as a **televisor.** These requirements are rather similar to those at the sending end where we required first a piece of apparatus for changing from light to electricity, and secondly a wireless transmitting equipment such as is used in the usual broadcasting.

We will leave the wireless receiving set alone for the present and deal with the televisor part of the receiving equipment. As a matter of fact the wireless receiving set required is very much the same as the valve receiver you are probably using every day for the reception of broadcast speech, etc., and possibly your wireless set could readily be adapted for television. It takes the varying electrical impulses from the aerial, magnifies or amplifies them, then passes them through a detector or rectifier, then further magnifies them, and finally, instead of passing them on to telephones or a loud speaker, passes them on to the televisor. We will deal with the best arrangements for, and the construction of, wireless receiving sets for television purposes later.

And now for the televisor itself, which translates the varying current from the wireless receiver back again into varying light and produces the image of the face at the transmitter.

In Fig. 85 **N** is a neon lamp of the plate type already described in Chapter III., and the terminals of this lamp are joined into the circuit of the last valve of the wireless receiver, more or less as the loud speaker or telephones are joined in the circuit of the last valve in a wireless receiving set. In this figure the plate **K** is the cathode of the lamp, and it is the illumination of this plate which builds up the image of the face televised. You will remember, of course, that if a varying pressure be applied to a neon over and above the striking pressure, we get a corresponding varying illumination.

In front of the neon lamp is a scanning disc, **S**, which, like the scanning disc at the sending end, is provided with 30 holes arranged in a spiral. This disc is mounted on the axle of a small electric motor and rotates with the motor armature.

Looking at the disc from the right in Fig. 85, the neon is fixed behind the right-hand half of the disc so that if the disc rotates counter-clockwise, viewed from the right of Fig. 85, each hole of the disc will sweep *upwards* in front of the plate K of the neon lamp: in fact the disc scans the plate K in the same directions as we said the light spot at the transmitter moved over the light area. The motor and disc are run at the same speed as the motor and disc at the sending end, viz. 750 revolutions per minute or 12½ per second.

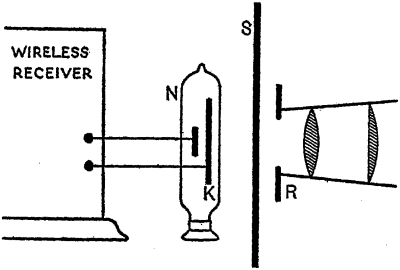


Fig. 85.

Next to the disc is a plate R with a rectangular opening: this merely adjusts the size of the picture and prevents any light coming from the neon into the observer's eyes except that required to form the picture.

Finally, to magnify the picture a convex lens (or two) may be placed in front through which the observer can view the picture which is built up by K. This lens must be so arranged that the distance between it and the neon is *less than the focal length* in which case a *magnified and erect* image will be seen on looking through it, as explained in Chapter II. Frequently the lens is not fitted to the instrument.

Now let us see how this arrangement works and gives us the image of the person televised. To simplify the wording we will again neglect the lens (with its reversing effect) at the

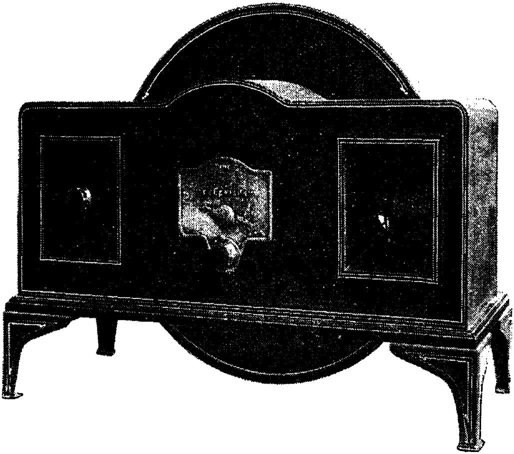
transmitter, and assume the projector lamp there is facing the right-hand half of the disc face, and that the disc is moving counter-clockwise.

Suppose hole 1 of the transmitting disc is just entering at the bottom right-hand corner of the light area, and hole 1 of the receiving disc is in a similar position with regard to the picture area on the plate K of the neon. Hole 1 of the transmitter moves rapidly upwards, and in step with it, hole 1 of the receiver sweeps upwards in front of K, and the result is a varying current from the photo-electric cells (depending on the light and shade at each point of the face as the light spot sweeps upwards), a modulated aether wave, a corresponding varying current through the wireless receiver, and corresponding varying extra pressures applied to the terminals of the neon lamp: and the result of this, as already explained in Chapter III., is a varying illumination on the plate K. The illumination of K at any instant, and therefore the light which comes through the hole to the eye at that instant, depends on the light thrown back by the part of the face opposite the hole of the transmitter at that same instant. (Remember also that the two holes are in corresponding positions at each instant.)

Hole 2 at the transmitter then sweeps out its strip over the face, and in step with it hole 2 of the receiver sweeps upwards in front of K, its path up K being adjacent to the path traced by the first hole. As in the previous case the result of this is a varying current from the photo-electric cells, a modulated aether wave, a varying current through the receiving set, varying extra pressures applied to the neon, and a varying illumination of the plate K. And the illumination of K and the light it sends through the hole to the eye at any instant depends on the light thrown back by the part of the face opposite the second hole of the transmitter at that same instant. All this applies to each hole as the two discs rotate.

Now bearing in mind what we have said about persistence of vision of the human eye, and that the televisor disc is going round at a speed of 750 revolutions per minute, you will readily understand that anyone looking into the televisor at the disc will not see the holes separately or, in fact, the disc

moving, but he will see an entire illumination built up of the various illuminations properly spaced out and positioned, the whole forming a picture of the face at the transmitting end.



The Baird Televisor.

The knob on the left controls the speed, and that at the centre the "framing" of the picture. The picture is viewed through the opening on the right.

In this chapter we have given you the essential principles of the wireless transmission and reception of television, and these you should master thoroughly before proceeding further. In the next chapter we will explain certain practical details in connection with the reception of television—and *reception* is the part of the business in which you will be mainly interested—and then we will be able to deal with the receiving apparatus as a whole—with the best arrangement for the "wireless" part of the apparatus, and its coupling with the televisor part to secure efficient reception.

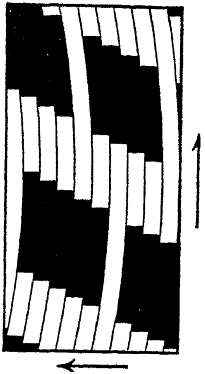
CHAPTER V.

PRACTICAL POINTS IN RECEIVING TELEVISION.

1. Starting to Receive on a Televisor.—Before explaining the cause and cure of certain things which may happen in the reception of television, it will be advisable to tell you briefly what you will see during the process of " tuning in " your televisor.

We will assume that the wireless receiver part of your receiving equipment is quite all right (we will deal with that in Chapter VII.), that your televisor is correctly joined up to it, and that you have your motor running, say, on the fast side.

The picture area you see is fairly uniformly illuminated and of a faint reddish colour. When sending begins you will notice that a number of darkish rectangles appear moving upwards and to the left as roughly indicated in Fig. 86.



Portion of Picture Area.
Fig. 86.

Now reduce the speed of the motor by rotating the knob on the instrument provided for that purpose. (Rotated in one direction this decreases the field rheostat of the motor and decreases the speed; rotated the other way it increases the speed.) The dark parts begin to slow down and to be replaced by some picture details which move mainly towards the left.

Continue to reduce the speed. As the speed gets nearer to the correct value—750 revolutions per minute—the movement to the left becomes gradually less and the vertical movement increases, the latter now consisting of more or less complete

pictures apparently hopping upwards. When you have reduced the speed down to the correct value, the picture will be quite stationary.

If you start to tune in with the motor running too slow matters are more or less the opposite to what we have described above. Thus the dark rectangles we mentioned will move downwards and to the right, and so on. At about half speed two fairly distinct and complete images may be seen, and four may be seen at about quarter speed, but we need not go further into these points.

Now having got the picture quite steady things may not be as they should. Your picture may be in two halves, *i.e.* split up the centre, the face appearing behind the back of the head: or it may be cut horizontally, the bottom part of a face, for instance, being at the top of the picture and the upper part of the face and head at the bottom of the picture. Both these "accidents," however, are readily repaired.

It is also possible—owing to certain defects—for a picture to be upside down, to be upside down and also split into two parts, to be reversed so that "right" becomes "left," etc.

We will now explain to you the cause and cure of these various defects.

2. Pictures Inverted, Reversed, and Split.—We have said that in television reception the disc at the receiver must run at the same speed as the disc at the transmitter, but this alone is not sufficient: they must also be *in step*, or, as we say, be *synchronised* or run in synchronism. Thus when the light spot from hole 1 of the transmitting disc is at the bottom right-hand corner of the light area and then sweeps upwards, hole 1 of the receiving disc must just be at the bottom right-hand corner of the picture area and then sweep upwards: when the light spot from hole 2 of the transmitter sweeps upwards giving the second light strip from the right, hole 2 of the receiver must sweep upwards, tracing out the second strip from the right on the picture area, and so on.

Suppose now that a person is being televised, and you set to work to receive the picture. We will take it that your disc is running at the correct speed and in the right direction

for proper scanning (bottom to top and right to left), but we will suppose that hole 1 of your disc comes into action just at the instant that hole 16 of the transmitting disc is coming into action, as shown in Fig. 87, where **T** is the transmitter and **R** the receiver. Now the beam from hole 16 of the transmitter sweeps up the middle of the person and at the same time hole 1 of the receiver sweeps up the extreme right-hand side of the picture area. Clearly then you get an image of the middle of the person on the extreme right of the picture.

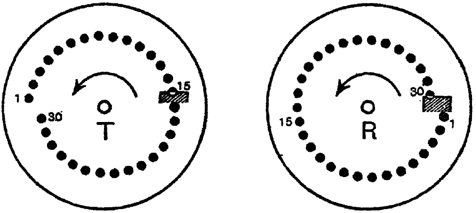


Fig. 87.

Again, when the beam from hole 1 of the transmitter sweeps up the right-hand side of the light area, say just partly over the shoulder of the person, hole 16 of the receiver will sweep up the middle of the picture area. Clearly then you get an image of the shoulder and its adjacent parts in the middle of the picture. Similar conclusions will be arrived at by taking other holes into consideration, and it will be clear that in such a case your picture will be in two halves as indicated in Fig. 88.

As a further exercise you should consider, say, hole 1 of the transmitter in step with, say, hole 7 and then hole 20 of the receiver. You will get similar results but, of course, different displacements of the picture.

It is not difficult to remedy this defect if it occurs when you start to receive. Adjust the rheostat in the field circuit of the motor (this is done by a dial knob on the televisor), so that the motor runs *just a little* faster or slower—make the

disc "skip" a few holes so to speak—until the picture is correct, and then let it settle into normal speed.

Fig. 88.

We have said that in the televisor the neon lamp is behind the right-hand half of the disc face as you look at the latter through the opening in front, and that the disc rotates counter-clockwise: this ensures that the "scanning" is in the right direction—bottom to top and right to left—the same as the movement of the light spot over the person at the sending end. Let us see, however, what would happen if you constructed your own televisor, and by mistake, fixed the neon behind the other half of the disc.

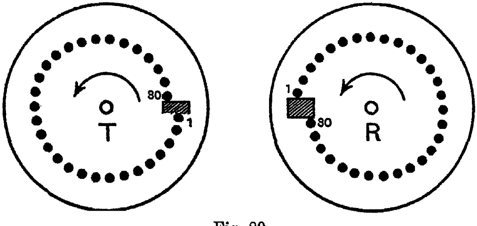


Fig. 89.

Suppose the relative positions at starting are as indicated in Fig. 89, **T** again representing the transmitter and **R** the receiver. The beam from hole 1 of the transmitter moves

up the right-hand side of the light area and at the same time hole 1 of the receiver moves *down the left-hand side* of the picture area, therefore you get an image *upside down* of the extreme

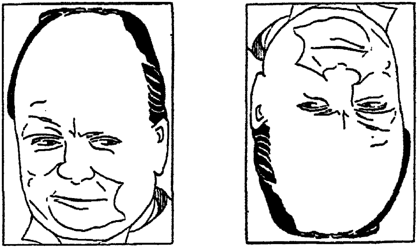


Fig. 90.

right-hand side of the person being televised on the extreme left-hand side of the picture area. This follows on with each pair of holes in turn, and the final result is as shown in Fig. 90: the picture is upside down.

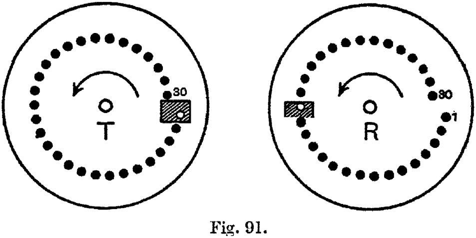


Fig. 91.

Again, suppose the discs are arranged at the start in correct corresponding positions as shown in Fig. 91. Then when the beam from hole 1 of the transmitter moves *up the right-hand side* of the light area, hole 16 of the receiver moves *down the centre* of the picture area, and gives in the centre of the picture

the white space and perhaps a part of the shoulder traversed by the beam from hole 1 of the transmitter. If you follow this out for a few holes you will see that the picture is again upside down, but this time it is split into two halves, as indicated in Fig. 92.

It is unlikely that your neon would be fixed by mistake in any other position, but as an exercise you should consider what would happen if it were placed in other positions behind the scanning disc. Thus suppose the discs were in the position shown in Fig. 91, but the neon behind the upper portion of the disc. Then as the beam from hole 1 of the transmitter sweeps up the extreme right-hand side of the light area,

Fig. 92.

hole 25 of the receiver sweeps horizontally across the neon. Holes 2, 3, 4, 5, and 6 of the transmitter follow in turn tracing out the corresponding strips of the light area, and at the same time holes 26, 27, 28, 29, and 30 of the receiver move in turn horizontally across the neon giving the corresponding images, each path across the neon being adjacent to and below the preceding one. Then the beam from hole 7 of the transmitter moves upwards, and at the same time hole 1 of the receiver moves across the neon, but its path will not be adjacent to and below the preceding one: it will be across the top of the picture area. By considering other holes in this way you will readily see that the picture is turned into the horizontal and is split into two unequal parts.

In fact as you move the neon round from its correct position into various positions behind the disc, the picture becomes more and more turned round, and is completely upside down in the position 180° away from the correct position, as already shown. Of course a picture could be formed properly with the neon in any position round the disc provided the arrangements for scanning the person at the transmitting end were made accordingly: thus it is the practice in Germany to fix the neon in the position last considered, *i.e.* behind the upper half of the disc.

If the two discs be in the correct positions as shown in Fig. 91, but the receiving motor happens to run the wrong way round, the picture will be upside down. Thus as the beam from hole 1 of the transmitting disc sweeps *up the extreme right-hand side* of the light area, hole 30 of the receiving disc (running clockwise) will sweep *down the extreme left-hand side* of the picture, and so on. Clearly the picture will be inverted. The neon is, of course, assumed to be in the correct position here, *i.e.* on the right of **R** in Fig. 91.

Finally, if the disc of the receiver were, by mistake, fixed on the motor axle the wrong way round, as shown in Fig. 92 (*a*), where again **T** is the transmitter and **R** the receiver, it is clear as the beam from hole 1 of the transmitting disc sweeps *up the extreme right-hand side* of the light area, hole 30 of the receiving disc sweeps *up the extreme left-hand side* of the picture, and so on. By following out the paths of other holes in turn it will be readily seen that the picture, although the right way up, is *reversed*, *i.e.* right becomes left: thus any movement of the person being televised to the left would be shown as a movement to the right in the picture. Draw the discs in the position indicated and verify this.

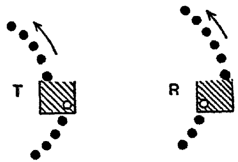


Fig. 92 (*a*).

The defects dealt with so far are all quite easily remedied —the first by the speed control as indicated, and the others by correcting the faults causing them.

3. Pictures not Centred.—It sometimes happens that the picture seen in the televisor is split horizontally with the bottom portion at the top and the top portion at the bottom, as shown in Fig. 93: you have probably often seen a similar "accident" on the screen at the cinema theatre.

In the televisor this defect is due to the wrong setting of the synchronising device in relation to the disc holes (Art. 4).

But as an exercise think out a possible explanation from what we have told you in Art. 2. Draw the transmitting and receiving discs as we did in that section, but let the receiving disc be so displaced that with hole 1 of the transmitter at the bottom of the light area, hole 1 of the receiver is half way up the picture area.

Hole 1 of the transmitter moves, say, half way up over the lower part of the object being televised, and at the same time hole 1 of the receiver moves up the upper part of the picture area: on the upper part of the picture we therefore have the lower part of the object. Hole 1 of the transmitter now moves over the upper half of the object, and at the same time hole 2 of the receiver moves over the lower half of the picture area: on the lower half of the picture we therefore have the upper part of the object.

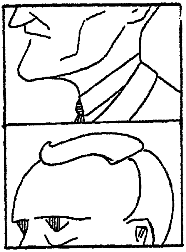


Fig. 93.

To remedy this defect a knob is fitted to the front of the televisor so that if this knob be rotated the entire carcase of the televisor motor is rotated: this is done until the picture is so moved vertically up or down that it is properly centred or "framed" as required.

4. Negative Pictures.—You know that if you compare a photographic print with its negative the light parts of the print are dark on the negative and the dark parts of the print are light on the negative.

Now in television it is possible to receive an image "the other way about," as indicated above, and it is referred to as a

negative picture. In such a case the fault lies not with the televisor but with the wireless receiver part of the receiving set, and we will explain the matter fully and show how such an "accident" may be guarded against when we come to describe the arrangement of wireless receivers for television in Chapter VII.

At present we merely want you to note that such a thing may happen, and that, when it does, the culprit is the wireless receiver.

5. Synchronising the Sending and Receiving Discs.—We have repeatedly mentioned that the motor and disc at the receiving end, *i.e.* in the televisor, must run at the *same speed* as the motor and disc at the transmitting end, and that the discs *must be in step* or, as we say, they must be **synchronised** or run in synchronism.

"Synchronism," to be exact, means more than mere equality in speed. Thus Big Ben in London and the clock at Trinity College here in Cambridge may run exactly alike inasmuch as their hour hands go once round the dial and their minute hands therefore twelve times round the dial in equal times over and over again, but if one gave the time as 20 minutes past 3 o'clock when the other gave it as 5 minutes past 4 o'clock they would not be in synchronism; for synchronism their hands must always be in corresponding positions, *i.e.* when one says 20 minutes past 3 the other must say the same, and so on.

As already indicated, in the Baird system of television the speed of the transmitting motor and disc is 750 revolutions per minute, and this, therefore, must be the speed at the receiver. Suitable small direct current motors—preferably shunt wound—can be purchased to run off an accumulator battery of from 6–12 volts, and the speed can be adjusted by means of the field rheostat: increasing this resistance increases the speed, and decreasing it decreases the speed. Suitable small motors can also be purchased to run off the mains—those of the "Universal" type can be used on either direct current or alternating current mains—and their speed can also be readily controlled. In the Baird televisor the rotation of a knob

on the front of the instrument enables the field rheostat to be varied.

We have seen that if the speeds are very much different instead of a steady image we get a series of patches travelling vertically and across: as the speed of the receiver approaches that of the transmitter, we begin to receive the image but with details distorted: finally, when the speed of the receiver is quite correct and the two in step, we get a stationary and correct picture. Now in order to keep the picture steady and the transmitter and receiver in step—the beam from a transmitter hole entering the light area and sweeping upwards in step with the corresponding receiver hole entering the picture area and sweeping upwards—it is clear that some *automatic* device becomes necessary if television is to be a commercial success. Synchronism must be maintained in some way which does not demand expert knowledge or expert "handling" on the part of anyone using the receiving apparatus.

It seems an exacting demand to require two motors separated by hundreds of miles to run at exactly the same speed and in step, but Baird's system of securing this is both very simple and very efficient, for he uses a part of the picture current or signal itself to secure this necessary synchronism.

Going back to the sending end for a moment we said that the beam from hole 1 passed out of the light area at the top *a little before* the beam from hole 2 entered at the bottom, that the beam from hole 2 passed out at the top a little before the beam from hole 3 entered at the bottom, and so on. This, of course, is done by adjusting the distance between the parts *a* and *b* of the shutter, shown in Fig. 82. The result of this is that when the top of each vertical strip has been reached there is a short interval of time when no light is falling on the light area, no light is being scattered to the photo-electric cells, the latter give no current, and, corresponding to this, there is no current impulse through the neon at the receiver. Remember that this short "no current" period occurs at the end of each strip, *i.e.* 30 times for one revolution of the motor and disc or no less than 375 times per second, since the disc rotates 12½ times per second. We have indicated this by a

black line at the top in Fig. 83: its depth is equal to the side of a hole of the disc.

Mounted on the axle of the motor of the receiving televisor —at the opposite end to the disc—is a steel cogged wheel provided with 30 teeth, *i.e.* the same number of teeth as there are holes in the discs. This wheel rotates inside a fixed iron ring with two pole pieces projecting from the inner circumference at opposite ends of a diameter. Coils of insulated copper wire are wound on these, and when a current passes through the coils the pole pieces are magnetised so that one is a north pole, the other a south pole. The face areas of these poles and the wheel teeth are equal, and the whole is so arranged that as the wheel rotates with the motor armature the teeth pass in turn exactly across the faces of the poles and quite close to them. All this will be clear from Fig. 94.

When running normally, a tooth is just half way across the face of a pole when the hole of the disc is just entering the black line area at the top of Fig. 83: the tooth is exactly opposite the pole when the hole of the disc is half way across the black line area, and the tooth is half out from the pole when the hole of the disc is completely in the black line area.

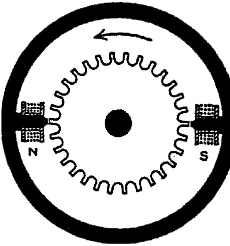


Fig. 94.

Now the coils on the two poles are joined in series and to the neon, so that when there is a "receiving" current through the neon (*i.e.* when a hole on the transmitter is in the light area) current will flow through the coils magnetising the iron cores. When there is no receiving current through the neon (*i.e.* when a hole on the transmitter is completely in the black line area) there will be no current through the coils, and the cores will not be magnetised. We will show you exactly how the coils are coupled in the circuit when we come to consider the wireless receiver part of the receiving apparatus in Chapter VII.

When a core is magnetised it will, of course, exert a certain pull on the tooth nearest to it. Now from what has been said above about the relative positions of a tooth and pole when a hole is passing into the black line area, it will be clear that when running correctly there will certainly be a forward pull on a tooth as it is approaching and entering under a pole, and a backward pull as it is leaving when the "no current" period is past and current again flows: but these backward and forward pulls on each tooth in turn may be regarded as neutralising each other on the whole, so that the receiving motor and disc are kept at the speed of the transmitting motor and disc, and the picture will be quite steady.

But suppose the receiving motor is running faster than the transmitting motor: then a tooth sweeps under and passes a pole while current is still flowing, and the core therefore still magnetised; hence the pole pulls the tooth back and retards the motor—puts the brake on, so to speak. Remembering that this is repeated with each tooth in turn, it will be clear that the effect of these "correcting impulses" will be to keep the receiving motor running at constant speed and in step with the transmitting motor. Further, if the two are once put correctly in step—*hole* 1 *of the transmitter in step with hole* 1 *of the receiver* and so on—they will remain in step. It is desirable in practice to set the receiving motor to run *just a little* faster than the transmitter, and then let the retarding action of the poles on the teeth keep the two in step and therefore keep the picture steady.

The above is a simple, automatic synchronising device which is really efficient: in practice with a modern televisor fitted with it the picture is perfectly steady and quite sharp and clear.

The principle of action of this toothed wheel used by Baird in his televisor, is *somewhat* similar to the "phonic wheel" device sometimes met with in alternating current electrical engineering work: there is, however, an essential difference between it and the phonic wheel, but this does not concern us here.

Previous to the above *toothed wheel method of synchronising*, Baird employed another method which also made use of the

"black line period" at the end of each strip. When the motors were in synchronism a little electromagnet at the receiver was automatically brought into the neon circuit just at the black line period: of course no current flowed through the coils of the electromagnet. If, however, the receiving motor ran faster than the transmitting motor the little electromagnet came into action before the black line period was reached, *i.e.* while current was flowing and its cores were therefore magnetised. In consequence the cores attracted a pivoted piece of iron, and when this was attracted it short-circuited a resistance in the fields of the motor: in other words, it reduced the resistance in the fields of the motor, and therefore reduced the speed.

The little electromagnet and its pivoted iron are spoken of as a *relay*, and the method is called the *relay method of synchronising*. In practice the receiver was made to run just a little faster than the transmitter, and then by means of the relay correcting action the two were kept in step. The method, however, has given place to the toothed wheel method previously described.

CHAPTER VI.

THE THERMIONIC VALVE AND ITS USES.

1. The Thermionic Valve.—Valves, as you know, are now almost universally used in radio reception, and for the very simple reason that they can do certain things better than any other piece of apparatus we know of, and the real reason they can do this is that they have a tremendous supply of electrons: these electrons are given off by a hot filament, rather like the filament of an electric lamp, inside the valve. There is no air in the valve.

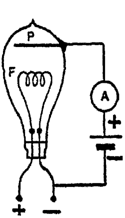


Fig. 95.

One of the earliest kinds of valves that was made was called the **diode**, and it is shown in Fig. 95. It consists of an ordinary **filament** electric lamp—the filament is marked F—fitted with a metal plate P which is called the **plate** or **anode** of the valve.

When the filament is heated in the usual way by passing a current through it from a cell—say an accumulator—joined to the points marked + and −, the heated filament gives off (negative) electrons; hence if P be kept positive by joining it to the positive pole of another battery, shown on the right, the negative electrons from F will be attracted towards the positive plate P. But electrons moving from F to P means, of course, that an electronic current is going from F to P (and this can also be worded " a conventional current is going from P to F ") and so the indicating instrument A will be deflected.

If the battery connections be reversed, the negative pole being joined to P, the current through the valve will stop: you can easily see that this is correct because if P is joined to the negative of the battery it becomes negative and repels the electrons from F, so that they cannot get across and therefore there is no current. If an oscillatory pressure be used instead

of a direct or continuous pressure from a battery, current will flow through the valve when the plate **P** is positive but not when the plate **P** is negative.

You will see therefore that the valve may be said to be like the crystal in the sense that a current can only flow through it in one direction. You should note particularly that *in order to get a current through* **A** *and the lamp, the positive pole of the battery must be joined to the plate*: a current in this circuit is spoken of as the "plate current" or "anode current."

To explain the use of a valve in wireless we must first say a few more words about it. The electrons are given off by the hot filament, and the higher the temperature the better will they be given off. One of the materials used is *tungsten*, and if this is used alone for the filament the valve is called a **bright emitter valve.** If certain other substances, *e.g. barium oxide* or *thorium oxide* are added we get the electrons given off at a much lower temperature and the valve lasts longer: such a valve is called a **dull emitter valve.** The number of electrons given off per second is enormous—several times a million times a million.

Again, the speed of the electrons is also enormous. Under the influence of the attraction of the positive plate they leave the filament with a speed of about 400 miles per second, but reach much higher speeds as they approach the plate.

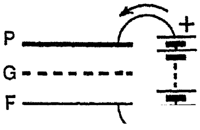


Fig. 96.

Now the modern valve which you use with your wireless receivers to-day is known as a **triode.** It has a filament **F** and a plate **P**, but it also has a wire **grid G** between them, the three being quite separate from each other (Fig. 96). Let the plate and filament be joined to a battery (from 30 to about 200 volts in ordinary cases of wireless receivers, and up to 300 volts and more in television), so that electrons are passing from filament to plate and therefore the (conventional) plate current from plate to filament. We are assuming of course that the filament is heated by an accumulator or other battery (not shown in Fig. 96).

Imagine now that the grid **G** between **P** and **F** acquires from some outside source a negative potential. It will repel the electrons coming from the filament and stop many of them from reaching the plate; hence the plate current will decrease. If the potential of the grid becomes positive it will attract the electrons from **F**, and (as **P** is at a higher potential in practice), they continue their motion through the grid holes to the plate; thus the plate current will increase.

To summarise—lowering the grid potential reduces the plate current: raising the grid potential increases the plate current.

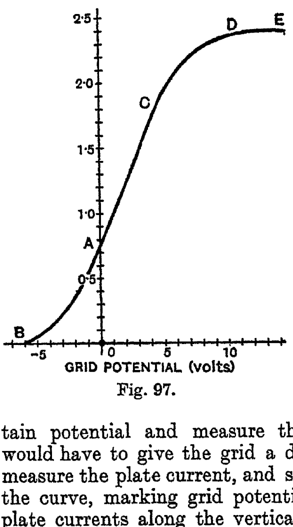


Fig. 97.

You will thus see that by varying the potential of the grid we can vary the flow of electrons through the valve from **F** to **P**, and therefore vary the plate current. The grid in fact, like a policeman, can be put on "point duty" inside the valve to regulate the traffic of electrons through the valve, and therefore to regulate the plate current.

Fig. 97 will show you better and more exactly how the potential of the grid alters the plate current. To get this curve you would have to give the grid a certain potential and measure the plate current. Then you would have to give the grid a different potential and again measure the plate current, and so on. Then you would plot the curve, marking grid potentials along the horizontal and plate currents along the vertical. Potentials to the left of **O** are negative and potentials to the right of **O** are positive.

Now when the grid has the negative potential **OB** it repels all the electrons from **F**, and there is no current, *i.e.* no "plate current." As the potential of the grid rises to zero (**O**), *i.e.*

becomes *less negative*, the plate current increases, as shown by the curve, to the value **OA**. As the grid potential becomes more and more positive the plate current rises more and more according to the curve **ACDE**. A curve of this kind is called a **characteristic curve of the valve**: you will see many such curves in valve manufacturers' advertisements.

Now here is another important point about valves. Although the electrons inside the valve move at such a tremendous speed their mass is so small that if we *suddenly* change the potential of the grid even by a small amount, we get an *immediate* change in the stream of electrons, *i.e.* in the plate current. Bear in mind that a change in the potential of the grid is *instantly* followed by a corresponding change in the plate current—there is absolutely no waiting. Our policeman is obeyed *at once.*

This is important, because in wireless the changes in the aerial oscillations (which of course are brought about by the speech, music, object being televised, etc., at the transmitting station) cause corresponding changes in the potential of the grid of the valve, and this causes corresponding changes in the plate current, and it is the plate current which goes through the telephones, loud speaker, or neon lamp and causes the speech, music, picture, etc., to be reproduced. If the plate current changes did not follow the grid changes instantly matters would be hopeless.

Another type of valve is also in use, especially for what is known as high frequency amplification (*i.e.* amplification or magnification *before* rectification—see Chapter VII.), and it is referred to as the **screened grid valve.** From what we told you in Chapter III. about condensers you will quite understand that there is *capacity* between the plate and grid of a valve, and one result of this may be that too much energy may be "fed back" from plate to grid: this causes "howling" in the receiver. This feed back can be cancelled by coupling the plate and grid outside by a coil and condenser suitably arranged, and this is often done as will be seen in Chapter VII.

The screened grid valve, however, has largely come to the rescue for this defect. It is specially made to have a small capacity between plate and grid, and, moreover, it is provided

with a *second* grid in between the usual grid and plate. This *screening grid* is kept at a *positive* potential, but at a less positive potential than the plate, and it therefore acts as a screen between the ordinary grid and the plate, and so prevents feed back. In the usual receivers it is customary to apply about 120 volts to the plate and about 80 volts to the screening grid. Sometimes the plate and screening grid are joined to the same pole of the battery, but a resistance is connected to the screening grid so as to " use up " so to speak the 40 volts thus making this grid's potential the necessary amount less than the plate potential.

Such a valve as the above is best suited to handle low voltages because when the plate voltage swings up and down very much it may reach a smaller value than the voltage on the screening grid, and this grid may then begin to pull electrons away from the plate. This trouble may arise if it is used for what is called low frequency amplification (*i.e.* amplification or magnification *after* rectification—see Chapter VII), where larger voltages are being handled. To overcome this another valve has been put on the market called a **pentode valve.** The pentode has another grid in between the screening grid and the plate, and this grid is joined to the negative of the filament: it therefore tends to repel back again any electrons which try to get from the plate to the screening grid.

You will note that the *diode* is a two " electrode " valve (plate and filament), the *triode* a three electrode, the *screened-grid* a four electrode, and the *pentode* a five electrode. The triode is the one most largely used, and we will deal with it in our further explanation of valve actions.

Wireless receivers, both for the ordinary broadcasting and for television, are sometimes run off the electric light mains, thus dispensing with batteries—either high tension (which supplies the plates) or low tension (which heats the filaments) or both—and valves have been specially constructed for the purpose. If the supply is alternating current it is changed to direct or continuous current for the high tension or plate supply: for heating the filaments alternating current can be used if special filaments are employed, but the more usual method is to pass the alternating current through a " heater "

inside the valve which radiates heat to the filament or cathode, *i.e.* the cathode is heated indirectly. In one type of valve for this purpose the cathode (or filament proper) is a nickel tube coated with a mixture of barium and strontium oxides which operates at a dull red heat: it is heated by means of a hairpin of tungsten (placed inside the tubular cathode but insulated from it by porcelain), through which the alternating current passes.

If the house supply is direct current the voltage must be cut down to the required values for the plate supply and filament supply by means of suitable resistances: if the supply is alternating current, transformers, as they are called (see Chapter VII), are used to cut down to the required voltages and, of course, in addition, the current must be rectified for the plate supply as indicated above. Smoothing devices—consisting of inductances and condensers—are also used to prevent any changes in the supply voltage, causing a hum in the receiver.

We will now set to work to examine exactly how a valve is used and how it works in a wireless receiver, and it will considerably help you to understand this if you first take a glance at Fig. 98 which shows you the general connections of a valve, etc., to a receiving aerial: we have purposely left out a few things in this figure which are actually used in a valve receiver because all we want you to do at present is to get a general idea of how a valve is joined up.

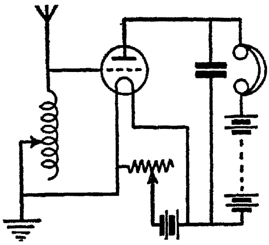


Fig. 98.

The **low tension battery** (2 to 6 volts) is shown at the bottom of the figure: it is usually one, two, or three accumulators, is used for heating the filament, and it sometimes has a variable resistance in its circuit, called a **filament rheostat,** so that the current given to the filament can be increased or decreased. With modern

valves the rheostat is not necessary for this purpose, but it can be utilised for other purposes. The **high tension battery** (30 to 200 volts in practice and 300 volts and more for television) is shown on the right: its positive pole is joined to the plate of the valve, and the telephones, etc., are in its circuit. The aerial inductance is joined between the grid and the filament. You need not trouble at present about the condenser which is joined across the telephones and battery.

When the waves arrive at the aerial, oscillations are set up in it. We thus have rapidly changing potential differences set up at the ends of the aerial inductance on the left, and these are applied between the grid and filament. The electrons in the valve immediately respond to these changes applied to the grid, with the result that we have corresponding changes (really magnified) in the direct current from the high tension battery in the plate circuit which, of course, causes the telephones to respond.

2. The Two Uses of a Valve in Radio Receivers.—In wireless receivers, both for sound reception and television, the valve is used in two ways, viz. (1) as a **rectifying detector,** similar to the crystal, and (2) as an **amplifier,** *i.e.* specially for amplifying or magnifying the signals so that ultimately a louder sound is produced, or more distant stations brought in or a picture obtained. A valve used as a detector also amplifies.

Again, an amplifying valve may be used to amplify the weak signals just as they arrive at the aerial, *i.e.* before they are passed on to the detector: this is called **high frequency amplification,** for the signals are magnified at high frequency. (In ordinary wireless this helps to bring in distant stations.) A valve can also be used to amplify after the signals have passed through the detector and are rectified; this is called **low frequency amplification,** and is used to further magnify the sound in the telephones or to enable a loud speaker to be used: it is also essential for television reception.

3. Using a Valve for Amplifying or Magnifying.—Consider for a moment the *steepest* part of the valve curve shown in Fig. 99, and suppose the grid of the valve (when no signals are being received) to be at a potential represented by **OA.** A

steady plate current will be passing, represented by **AF**. Now suppose wireless waves arrive and oscillations are conducted to the grid. These will vary the voltage of the grid, the positive half waves causing the grid potential to be higher and equal to **OB**, say, and the negative half waves causing it to be an equal amount lower, *i.e.* equal to **OC**.

When the grid potential is **OB** the plate current will have increased from **AF** to **BE**, and when the grid potential is **OC** the plate current will have fallen to **CD**. Thus as the grid potential swings backwards and forwards (due to the arriving waves) between **OB** and **OC**, the plate current swings backwards and forwards between **BE** and **CD**, and further, the plate current changes follow the grid potential changes, and therefore the incoming waves, no matter how rapid the changes may be.

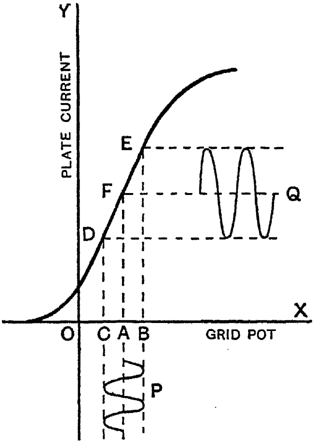


Fig. 99.

As we are working on the very steep part of the curve, however, a small jump from **C** to **B** causes a big jump from **D** to **E**, and this will be more pronounced the steeper the curve. It will be seen by comparing the two curves **P** and **Q**, where **P** represents the potential swings applied to the grid from the aerial and **Q** the current swings in the plate circuit, that the swing of **Q** will be bigger and bigger the steeper the curve. Thus the valve has amplified or magnified the variations impressed upon the grid. In amplification the valve should be so arranged that the steep part of its curve is used.

4. Using a Valve for Rectification or "Detection."—Think carefully of this: In a crystal receiver the aerial oscillations are passed on to the crystal, the swings in one direction are wiped out by the crystal and the swings in the other direction pass on to the telephones: in the latter, then, we have a current which runs in one direction only, although it varies up and down in strength.

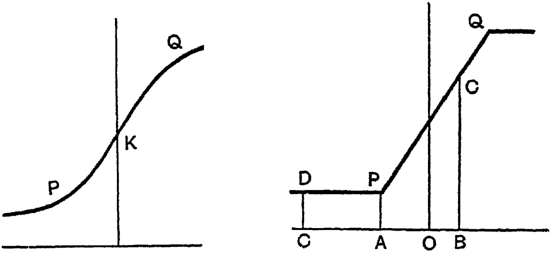
In a valve wireless receiver the aerial oscillations are passed on to the grid, and the result of this is that we get a corresponding (but larger) variation in another current—the plate current—and this latter current, although it varies up and down in strength, always runs in one direction. The electrons in this plate current always go from the filament through the valve to the plate and back through the battery to the filament: you cannot get the electrons to go the other way from plate to filament through the valve. And of course it is this varying plate current, always running in one direction, which works the telephones.

But, nevertheless, there are "best ways" of arranging a valve for so-called "detection." Now there is a lot of important and interesting theory underlying the action of a valve working in this capacity, but of course you do not want to know this, and it is not necessary at present. We will merely give you two important points which you really must know.

Consider for a moment the parts of the valve curve where the *bending* is greatest, *i.e.* the "knees" **P** and **Q** (Fig. 100 (*a*)). So that you may grasp the idea we have exaggerated these in Fig. 100 (*a*), and to make the explanation still simpler we will exaggerate them still more for a moment as in Fig. 100 (*b*).

With this curve, let the grid potential be equal to **OA** when no waves are passing, in which case the plate current is **AP.** When wireless waves arrive the negative half-wave lowers the potential of the grid to **OC,** but the plate current does not alter—it is **CD,** which is the same as its original value **AP.** When the positive half-wave arrives the grid potential rises to **B** and the plate current becomes **BC.** We thus get a plate current variation from **AP** to **BC** when the positive half-waves arrive, but not when the negative half-waves arrive. The valve is therefore responding, as it were,

to swings in one direction only, just similar to a crystal. To utilise this rectifying property then, the valve must be so arranged that the bending part of the curve is used.



(*a*) Fig. 100. (*b*)

Fig. 101 shows more exactly, and after the style used in Fig. 99, the rectification action we are just considering. The grid is given the negative potential represented by **OA**, and again we are using the bottom bend of the curve. Here, however, we have taken a "modulated" wave as coming up to the aerial, and a corresponding pressure fluctuation being applied to the grid: this is shown at **P**. The resulting plate current changes are shown at **Q**: it will be noted that the swings upwards at **Q** are bigger than those downwards—the latter in fact being practically wiped out—on the whole there is an increase of plate current. Note also that owing to the straight nature of the curve above the bend, the changes at **Q** copy those at **P**, *i.e.* there is, as we say, proportionality between input (**P**) and output (**Q**).

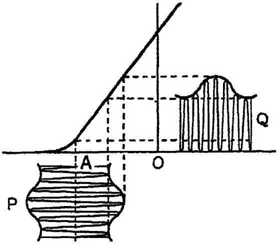


Fig. 101.

This method of rectifying by a valve is called **anode bend rectification**, and Fig. 102 shows a valve joined to an aerial circuit for this form of rectification. You will notice we have drawn four cells in the low tension battery, the filament being joined to two of these. A resistance (called a *potentiometer*) joins the poles, and by the moving contacts shown the potential of the grid to begin with may be adjusted so that it falls at the point **P** (Fig. 100) where the curvature is changing rapidly. This method of rectification is largely in favour for wireless circuits for television.

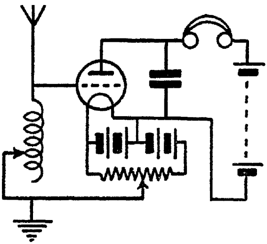


Fig. 102.

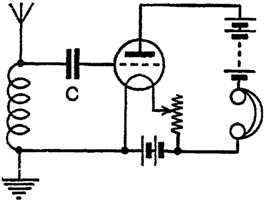


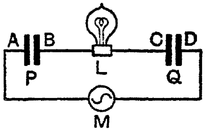
Fig. 103.

Your wireless receiver which you use for the reception of every-day broadcasting probably uses what is called **grid leak rectification.** Look at Fig. 103. You will see that a condenser **C** has been put in the grid circuit of the detector valve (this must be done in most cases if the detector valve follows another valve, as will be seen later). This condenser does not stop the high frequency aerial impulses from reaching the grid, for an alternating current can " work through " a condenser.

You can see that this is true from Fig. 104. During the first half cycle of the alternating current, electrons rush, say, from **M** to **A** (making **A** negative), an equal number rush from **B** to **C** (making **B** positive and **C** negative) and an equal number rush from **D** to **M** (making **D** positive). During this half cycle, therefore, there has been a flow of electrons through the lamp from **B** to **C.**

Clearly, during the next half cycle of the current the flow of electrons will again occur, but in the opposite direction, viz. **M** to **D**, **C** to **B**, and **A** to **M**: during this half cycle, therefore, there has been a flow of electrons through the lamp from **C** to **B**.

Thus although there is not a current conducting road right round the whole circuit, the movement of electrons to and fro in the part **AMD** causes a corresponding movement of electrons in the part **BC**, and we say that the condensers do not stop the "action" or the "effects" of the alternating current: but bear in mind there is no flow of current through the dielectrics which are insulators.



P, **Q** = two condensers.
L = lamp.
M = alternator for generating an alternating current.
Fig. 104.

Now going back to Fig. 103. When the electrons stream over from the filament to the plate some will get caught in the grid whenever the grid becomes positive, and of course when the grid becomes negative we know that it is also getting electrons. Thus the grid tends to become choked with electrons (which, of course, reduces the plate current), and somehow we must allow these to escape. If there were no condenser **C** these electrons would be able to pass along to the aerial and back to the filament, but as **C** is there they cannot, for a *direct* current cannot pass through a condenser. If, however, we put a resistance coil across the condenser, as shown at **R** (Fig. 105), these electrons will be able to escape all right and the grid will be brought to its normal condition ready to be again properly influenced by the aerial oscillations working through **C**. This coil **R** is called a **grid leak**.

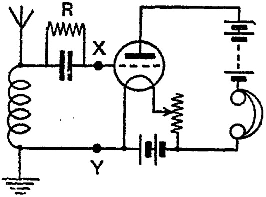


Fig. 105.

If the detector valve in a wireless receiver has another valve in front of it, the grid leak is not joined *across* the condenser but between the points **X** and **Y**, shown in Fig. 68, this *must* be done in most cases for a reason which we will explain later. In both cases note that **R** connects the grid with the *positive* of the low tension battery.

There is much more which should be said about this grid leak and condenser method of using a detector valve if we wish to be scientifically complete and precise, but it is not necessary for beginners. Note, however, that each time a group of oscillations is received in the aerial the grid is left with a large negative potential (and the plate current *reduces* in step with this) which gradually returns to the normal value. It will be apparent therefore that in grid leak rectification there is a *decrease* in the mean plate current when a signal is received, whereas in anode bend rectification there is an *increase* in the mean plate current as previously indicated.

For sound reception this difference between the two methods is immaterial for the telephones and loud speaker work all right with both: in television both methods of rectification will also work, but the question of getting a negative picture is partly connected with this, as will be seen later.

For sound reception grid leak rectification is largely used: for television reception anode bend rectification is perhaps, on the whole, preferable.

5. Types of Valves.—The filament is usually a straight wire or loop of tungsten or thoriated tungsten, or it may consist of a central metallic core of platinum or nickel coated with a mixture of barium oxide, strontium oxide and sometimes also with calcium oxide.

The grid may consist of tungsten, nickel, or molybdenum in the form of a spiral or mesh cylinder surrounding the filament, or it may consist of two perforated plates, one on each side of the filament, the two plates being connected together. Various modifications are used by different makers.

The anode or plate is usually of tungsten, nickel, or molybdenum, in the form of a cylinder surrounding the grid if the

latter is cylindrical, or in the form of plates if the grid is in that form. Here, again, there are various modifications.

The bulb of the valve is exhausted: if completely exhausted the valve is called a *hard* valve, whilst if traces of gas remain it is called a *soft* valve.

Fig. 106.

Fig. 107.

You will learn more in a few minutes about the construction of modern valves by examining some actual valves at your wireless dealers than you will by spending hours in reading about them, and all numerical details can be gathered from the makers' catalogues. Fig. 106 shows a typical triode valve —the Osram.

You will notice that the valve has four legs. The two ends of the filament are joined to two of these, the plate to a third.

and the grid to the fourth. The receiver is fitted with a "valve holder," as it is called, which is provided with four sockets into which the four legs of the valve are plugged. The valve legs (and of course the sockets) are unequally spaced so that the valve can only be plugged in in the right position.

An Osram screened-grid valve is shown in Fig. 107. The plate or anode is connected to the terminal at the top of the valve, and the screening-grid is connected to the leg which,

Fig. 108.

Fig. 109.

in the triode valve, is connected to the plate: the screened-grid valve can therefore be used with the same four socket type of valve-holder as the triode.

The general appearance of a pentode valve—the Cossor—will be gathered from Fig. 108. The terminal at the side is

connected to the "screening" grid, *i.e.* the grid which is given a positive potential.

You will probably come across valves with five legs instead of four, as in the cases above. As already indicated in some valves to work off alternating current mains, the ordinary filament is replaced by a specially coated tube or cathode through the inside of which passes the "heating element" which carries the alternating current: in such cases an extra leg is fitted for the cathode (Fig. 109). Pentodes also are sometimes fitted with a fifth base pin (instead of a side terminal) to which the screening grid is attached. And A.C. separately heated valves sometimes have a side terminal for the cathode.

CHAPTER VII.

THE WIRELESS RECEIVING SET IN TELEVISION.

1. Introduction.—As already indicated some form of wireless receiving set is necessary—in addition to the televisor dealt with in Chapter IV.—for the reception of television, and it is possible that your present wireless receiver may, with certain modifications, be suitable for the purpose. In this chapter we propose to outline for you wireless receiving circuits which have been found specially suited for television, but before doing that we will go very briefly into the principles underlying reception in general, for without some knowledge of these principles you cannot possibly understand the modern wireless receiver whether for sound reception or television.

Again, if you look at any modern wireless receiving circuit in any of the numerous wireless journals of to-day, you will probably come to the conclusion that it is a dreadfully complicated business. This is largely due to the fact that tremendous progress has been made in recent years both in wireless components and wireless circuits with the object of getting the highest quality of reproduction and, of course, these devices are incorporated in all diagrams of the circuits, with the result that they appear rather alarming to a beginner. We will therefore take first a few simple connections with as few complications as possible, to show the general principles, and then apply the ideas to modern receivers.

Now before going further you should examine again Figs. 102, 105 merely to get the general idea once more of a valve circuit connections: practically, however, those two particular circuits would not work nearly so well as the actual circuits you will get presently, and much more has to be done to them for loud speaker work or television, but that is not the point just now: first make sure of the outline—the skeleton so to speak—and details can then readily be filled in.

2. Reaction or Back Coupling.—It will be clear that some of the energy passed from the aerial to the grid circuit will be dissipated or wasted in the resistance of the grid circuit, and in consequence the amount of incoming energy available for the valve to work with will be reduced.

Clearly, if this dissipated energy can be made good by adding energy in some way to the grid circuit from some other source, the voltage variations between the grid and filament will be greater, the corresponding changes in the plate current will be greater, and signal strength will therefore be increased. This is accomplished by the arrangement shown in Fig. 110, and is known as *reaction*, or *back coupling.*

In the figure L_2 is an inductance, called the **reaction coil,** in the plate circuit of the valve: it is coupled to the inductance L_1 in the aerial and grid circuit, the distance between the two coils being usually variable: this variable coupling is obtained by mounting L_1 and L_2 in a two-coil holder such as was shown in Fig. 58. The varying current in the L_2 and plate circuit acts inductively on L_1, thus adding energy to the L_1 and grid circuit, and by suitable arrangement of the value of the reaction coil L_2 and the distance between L_1 and L_2, *i.e.* the coupling, this energy can be made to help that in the grid circuit, and to make up for the energy dissipated in this circuit: in other words, energy is being fed back from the plate circuit to the grid circuit, to make up the loss there.

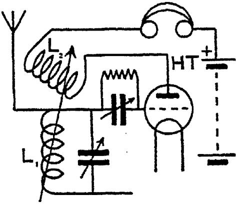


Fig. 110.

It looks at first as if the signal strength could be increased in this way indefinitely, but there is a limit. If you feed back more than a certain amount of energy into the aerial and grid circuit the receiving set breaks into self-oscillation and begins to act as a transmitter as well, *i.e.* it sends out waves. Music and speech become distorted, howls and squeaks result, and you join the ranks of the "oscillating fiend"—that unmitigated nuisance to all listeners in the vicinity.

The object to be aimed at in tuning is to get the reaction coil as close to the other as possible without actually falling into self-oscillation, but you should turn it away immediately on the first sign of oscillation. Experience will soon teach you when this stage is approaching.

Another method of obtaining reaction is to join a small variable condenser between the plate of the valve and the side of the coil which is connected to the grid: a little consideration will show that the explanation of the action is somewhat similar to the preceding.

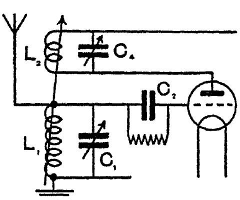


Fig. 111.

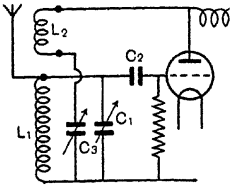


Fig. 112.

Fig. 111 gives the outline of another method. Here the reaction coil L_2 may be fixed in relation to L_1, and the reaction controlled by the variable condenser C_4. Another plan is to have L_2 movable as in the case first considered: when a signal has been tuned in, L_2 is brought nearer to L_1 but not sufficiently to start the set oscillating, and then C_4 is adjusted until the best signal strength is obtained. Fig. 112 gives yet another method in which L_2 is fixed and the reaction controlled entirely by the condenser C_3. All these methods, in various forms, are used in wireless receivers to-day.

3. Amplifying Valves.—In Chapter VI. we laid stress on the fact that a valve *magnifies*, *i.e.* that the current variations in the plate circuit are bigger than the variations applied to the grid from the aerial. That being so, why not use more than one valve?

Suppose as a simple example, a particular valve magnifies four times, and *somehow or other* (you will see *how* presently) we join its plate to the grid of another valve, thus passing on its magnified variations to the second valve: this valve will again magnify say, four times, so that in the plate circuit of this second valve the changes will be sixteen times as strong as the original ones from the aerial. And if we similarly join the plate of this second valve to the grid of a third valve, which again magnifies, say, four times, the variations in the plate circuit of this third valve will be sixty-four times as strong as the originals, and if the plate circuit of this third valve contains the telephones or loud speaker or neon lamp, good loud signals or good " picture " signals will be obtained.

Valves used for the express purpose of amplifying or magnifying are called, as we have stated on several occasions, amplifying valves.

Again, as we also have explained already, a valve may be specially used to amplify or magnify the weak signals just as they arrive at the aerial, *i.e.* before they are passed on to the detector valve: this is called **high frequency amplification,** for the signals are magnified at high frequency, and the method is used, amongst other purposes, to increase the range, *i.e.* to enable distant stations to be received. A valve may also be used to amplify the signals after they have passed through the detector valve: this is called **low frequency amplification,** and is used to increase the volume of sound in the telephones, or to enable a loud speaker to be used or, in television, to enable a " picture " to be obtained. Although there are certain special features about high frequency amplification and others about low frequency amplification, the general principle is much the same in both.

In the case of a two-valve receiving set consisting of a high frequency amplifying valve followed by a detector valve, the action is briefly this: The varying potential differences set up in the aerial inductance are applied between the grid and filament of the amplifying valve, which valve is, of course, arranged to work on the steep part of its characteristic curve. Corresponding *but magnified* changes in current are produced in the plate circuit of this valve, as already explained, and

as this circuit contains either a resistance or inductance or condenser, corresponding but magnified variations in the potential differences across them are produced. These amplified potential differences are applied to the grid of the second valve (which valve is, of course, arranged to work as a detector), and the action is then the same as in the case of a single valve (detector) circuit already referred to.

A similar explanation applies to the case of a low frequency amplifying valve following a detector valve. Further, two or three stages of high frequency amplification may precede the detector, but in practice the number is limited owing to the tendency to set up oscillations: several stages of low frequency amplification, however, often follow the detector valve.

There are various methods of arranging valves: one as a detector, and the others as high frequency or low frequency amplifiers; and we will first give you the general principles before passing on to actual modern receiving circuits.

4. Principles of Coupling Low Frequency Amplifying Valves to a Detector Valve.—Before we go on to the actual methods of coupling it will help you wonderfully if you first consider Figs. 113 and 114, where we are imagining a low frequency amplifying valve to be following a detector valve.

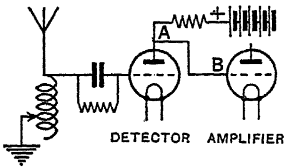


Fig. 113.

We want to pass on the current variations in the plate circuit of the first valve to the grid of the second, and in Fig. 113 we have drawn a line **AB** to represent a wire joining this plate and grid. Now as a matter of fact this is hopeless because the *grid* of the second valve is joined to the positive pole of the high tension battery: in fact it practically becomes a plate, and the valve will not work. What then are we to do? We must get the current variations —the impulses—to pass along from the plate to the grid, and

at the same time we must protect the grid from the positive pole of the high tension battery.

Well now we know that a condenser will allow an alternating or a varying or a surging current to "work through" it but will not allow a steady current to "flow" through it, and this suggests that one method would be to put a condenser in the path **AB** as shown in Fig. 114: this condenser will let the magnified surges from the plate of the first valve work through to the grid of the second, but it will stop any steady current from the plate battery getting along to the grid, and that is exactly what we want. We can now consider the various methods of coupling which in some form or other are used in all wireless receivers.

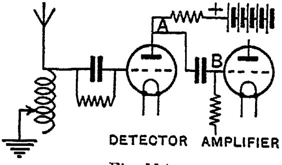


Fig. 114.

The first method we will deal with uses what is called a transformer: hence it is referred to as **transformer coupling.**

A transformer is merely a simple device in which the inductive action of one circuit on another—a primary coil on a secondary coil—is used: it is in fact a practical application of the experiment referred to on page 62. A low frequency transformer consists of two coils—a primary **AA** (Fig. 115) and a secondary **BB**—quite separate from each other and wound upon an iron core so as to increase the magnetic lines and therefore the inductive effect: the ends of the coils are brought out to four terminals as shown.

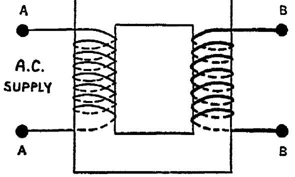


Fig. 115.

Transformers are used with alternating (or varying) currents, so that the primary current is constantly changing. The

varying current in the primary produces a varying magnetisation of the iron core and varying magnetic lines in the secondary, which results in varying induced currents in the secondary.

The induced pressure in the secondary depends on the number of turns of wire in it compared with the number of turns in the primary. Thus if the secondary has 10 times the number of turns that the primary has, the pressure induced in the secondary is roughly 10 times the pressure applied to the primary, *i.e.* the ratio of transformation is roughly 10 : 1. This is, of course, neglecting all losses of energy in the transformer. Further, since we cannot gain energy by the transformation it follows that the current in the secondary must be proportionally less, *i.e.* in the above case the current in the secondary is about $\frac{1}{10}$ of the current in the primary.

Similarly, if the primary has 10 times the turns that the secondary has, the pressure induced in the secondary is roughly $\frac{1}{10}$ of the pressure applied to the primary, and the secondary current is about 10 times the primary current.

A transformer which has more secondary turns than primary turns and which, therefore, raises the pressure, is called a **step-up transformer**, and one in which the secondary has fewer turns than the primary, and which, therefore, lowers the pressure, is called a **step-down transformer**. Sometimes the iron core is arranged to surround the coils.

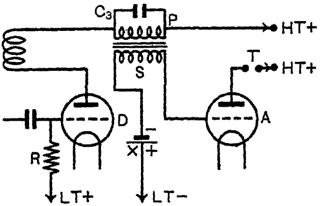


Fig. 116.

Fig. 116 shows the arrangement for transformer coupling, **D** being the detector valve and **A** the low frequency amplifying valve. The primary **P** of the transformer is put in the lead from the plate of **D** to the positive of the high tension battery and the secondary **S** is joined to the grid of **A** and to the negative of the low tension battery. It is essential to work the amplifying valve on the straight steep part of its characteristic curve and with most modern valves, to ensure this, it

is necessary to make certain that the grid is given a certain negative potential bias. To this end a few dry cells (grid battery) are inserted at **X**, the negative terminal being joined through **S** to the grid of **A**.

Note that the grid leak **R** of the detector valve is joined to the positive of the low tension battery. The condenser C_3 (about ·001 microfarad capacity) across the primary **P** is used in order to "by-pass" any high frequency current. Condensers are frequently used across the high tension battery for the same purpose.

The action is simple. The rectified current variations in the plate circuit of the detector valve **D** produce corresponding variations of potential on the primary **P** of the transformer, and these produce by induction corresponding variations on the secondary **S**. These latter are applied between the grid and filament of **A** operating as an amplifier with the result that on the output or plate side of this valve there are corresponding but amplified variations which work the telephones or loud speaker placed at **T**.

Another method of coupling known as **resistance-capacity coupling** is shown in principle in Fig. 117. The resistance-capacity coupling **RC** is in the plate circuit of the detector valve **D**, being joined between the plate of that valve and the positive of the high tension battery—in the place, in fact, occupied by the primary coil **P** in the preceding circuit. **RC** should have a resistance of about 100,000 ohms. The by-pass condenser C_3 across **RC** performs the same duties as were mentioned above.

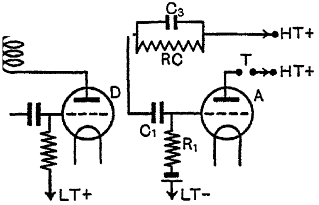


Fig. 117.

In this case the rectified (and magnified) current variations in the plate circuit of **D** produce corresponding variations of potential on **RC**, and these are applied to the grid of the amplifying valve **A** through the coupling condenser C_4 (capacity ·05 to ·25 microfarad).

With this coupling condenser it is necessary to use a high resistance R_1 between the grid and filament to act in a similar way to the grid leak of a detector valve. This high resistance R_1 is joined to the *negative* terminal of the low tension battery or to the *negative* of the grid bias battery shown in the figure. The resistance R_1 may have a value of one megohm although sometimes a smaller value—·5 or ·2 megohm—will give better results. A greater high tension voltage is necessary in the plate circuit of **D** in order to compensate for the fall in voltage across **RC**.

Resistance-capacity coupling does not give as much magnification as transformer coupling but it is much freer from distortion defects.

Yet another method of coupling—known as choke coupling or **choke-capacity coupling**—is also employed. A choke or choke coil is simply a coil of wire of low resistance wound upon an iron core and having therefore a large amount of self-inductance.

A circuit using this method of coupling is identical with that of Fig. 117, the choke coil merely taking the place of the resistance **RC** in that figure.

Various applications and some modifications of the above methods of coupling low frequency valves are used in all modern wireless receivers, as will be seen presently.

5. Principle of Coupling High Frequency Amplifying Valves to a Detector Valve.—One of the most popular methods of coupling a high frequency amplifying valve to a detector valve is that known as **tuned-anode coupling**, shown in Fig. 118, where **A** is the high frequency amplifier and **D** the detector.

In the plate circuit of **A** is a coil L_3 and a variable condenser C_2 in parallel with it, the value of C_2 being ·0002 or ·0005 microfarad and L_3 a No. 50 or 75 coil for the broadcast band. Reaction can be obtained by coupling the coil L_2 in the plate circuit of the detector valve with the aerial coil or with the anode coil L_3.

In this arrangement both the aerial circuit and the L_3C_2 circuit are tuned to the desired frequency (and wave length). The varying potentials applied to the grid of the amplifying

valve **A** produce amplified oscillations in the plate circuit of **A**, *i.e.* corresponding (amplified) potential differences are set up across L_3C_2, which is tuned to resonance with the oscillations. Finally these are fed to the grid circuit of the detector valve, the plate circuit of which includes the telephones.

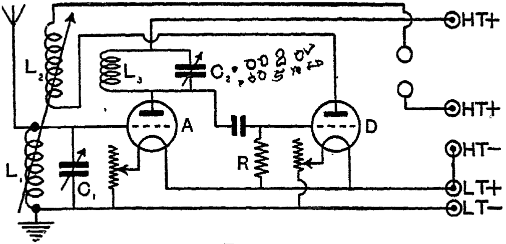


Fig. 118.

Another method of coupling known as **transformer coupling**, is shown in Fig. 119. A transformer for this type of work, *i.e.* for use with high frequency amplifying valves is called a high frequency transformer. It works on exactly the same principle as a low frequency transformer, the essential difference however being that a high frequency transformer must *not* have an iron core.

Now referring to Fig. 119 the secondary **S** of the transformer in the plate circuit of the amplifying valve **A** is connected as indicated between the grid and filament of the detector valve **D.** Since the aim is to apply as high a voltage as possible to the grid of **D**, the secondary **S** should be tuned as well as the primary **P**, but it is found that with the tight coupling which

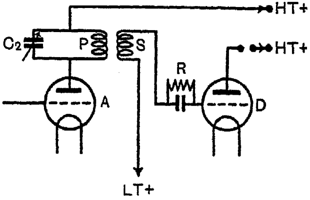


Fig. 119.

exists between **P** and **S** in practice (**P** and **S** are *fixed* close together and the coupling is said to be *tight coupling*) the one tuning condenser $\mathbf{C}_2$ in the primary tunes both **P** and **S.** The capacity of $\mathbf{C}_2$ is about ·0002 microfarad.

The grid leak **R** of the detector valve in this circuit may be placed across the grid condenser, for **S** is quite separate from **P** (and the positive high tension), and is joined to the positive of the low tension battery.

A reaction coil from the plate of **D** may be coupled to the aerial inductance or to the transformer windings: sometimes it is in two portions connected in series, reaction being applied to both the transformer windings and the aerial inductance.

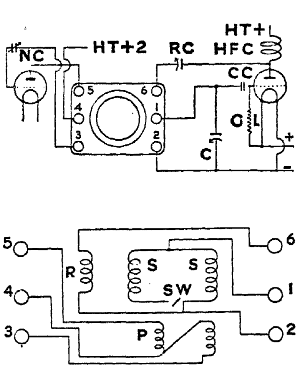


Fig. 120.

The Lewcos six pin dual range coil (D.A.P.) is put on the market in a form suitable for use as a high frequency transformer, and this is largely used in modern receivers. A diagram of the coil arrangements is shown in Fig. 120, **S** being the secondary winding, **P** the primary winding, and the six terminals being numbered 1 to 6. It will be noted that the primary is " split," terminal 4 being joined to the middle of it.

Fig. 120 shows the transformer coupling the high frequency valve on the left to the detector valve on the right. The coil **R** in Fig. 120 is termed the reaction winding. The reaction condenser **RC** communicates with **R** *via* terminal 6, its other pole being joined to the plate of the detector valve. You will see, therefore, that the circuit of Fig. 120 utilises the third method of reaction given in Art. 2.

NC is what is called a "neutralising condenser": its use will be explained presently. **SW** is a switch which is altered according to whether the ordinary broadcast band of wavelengths or the longer waves are to be used. Go carefully through the connections in Fig. 120 and you will see they are applications of the principles already dealt with.

Yet another method of coupling—known as **resistance capacity coupling**—between the high frequency a[illegible] valve and the detector valve is shown *in outline* in [illegible] 21, and you will understand the circuit from what has [illegible] said in Art. 4.

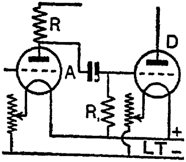


Fig. 121.

This coupling method does not lead to the degree of amplification which is obtained from the preceding tuned arrangements. On the other hand it gives very good results, particularly on high wave lengths, the amplifying circuits are not so liable to self oscillation, the resistance of the plate circuit is constant over a big range of frequencies, and distortion is a minimum. Of course additional high tension is required to compensate for the fall in voltage across **R**. In **choke coupling**, a choke replaces **R**.

One of the greatest drawbacks to the use of high frequency amplifying valves of the triode type is that there is a great tendency for the receiving set to start oscillating. This is due to the fact that there is often marked capacity inside the valve between the plate and grid, and this capacity acts just in the same way as the reaction condenser which was referred to in dealing with reaction: it feeds back energy from the plate circuit to the grid circuit, and if this be excessive, oscillations are set up.

One method of partly controlling or *neutralising* this is to employ a potentiometer and to give a slight positive potential bias to the grid of the high frequency amplifying valve which will damp down the effect of the valve capacity. The method is indicated in Fig. 122, where **P** is the potentiometer.

Another method is to use what is called a **neutrodyne circuit.** Imagine a point to be selected on the plate side of

the H.F. valve which has a potential at any instant of *opposite sign* to the potential of the plate at that instant. Imagine further that this point is joined through a variable condenser to the grid of the valve. Clearly it will be possible to feed back energy to the grid circuit *opposite* to the feed back due to the valve capacity, and by adjusting the capacity of the variable condenser it will be possible to make these two opposing influences exactly equal so that they balance each other. The impulses delivered by one will be equal and opposite at any instant to the impulses delivered by the other, so that the set as a whole will remain quiet and stable: this is the elementary principle of the neutrodyne circuit.

The modern screened grid valve is, however, rapidly replacing the simple triode for high frequency amplification. The extra grid between the usual grid and the plate is kept at a positive potential, the inter-electrode capacity between plate and grid is thus reduced to a small quantity and retro-active coupling through anode-grid capacity is reduced to a minimum.

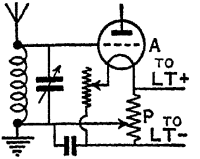


Fig. 122.

In addition, unwanted coupling between the grids and plates of screened grid valves (or other high frequency valves) and the circuits outside the valve is prevented by using metal (copper or aluminium) screens or partitions (see Art. 2 of Chapter I.). This will be seen in the circuits which follow.

6. Complete Receiving Circuits.—A modern and efficient four valve receiver consisting of one stage of high frequency amplification followed by a detector and two stages of low frequency amplification is shown in Fig. 123, a screened grid valve being used for the high frequency amplification.

The aerial coil L_1 is of the plug in type provided with three tappings as shown, to any of which the aerial is connected. Selectively and signal strength will be different in the three cases, and you must simply try all and see which suits your purpose best. For the reception of waves up to about 500

Coming to the detector valve V_2 it will be noted that grid leak rectification is employed, and that the grid leak R_1 communicates as usual with the positive of the low tension battery. Resistance-capacity coupling is used between V_2 and V_3, the resistance R_2 being about ·25 megohms. X is a choke coil, and *via* X and R_2 the plate of the detector valve is joined to the positive of the high tension battery. The value of this H.T. positive for the detector depends on the type of valve, and may be of the order of 60 volts. The resistance R_3 may be about a megohm: it communicates with the negative of the low tension battery, and in this circuit is the grid biassing battery B_1, its negative pole being joined through R_3 to the grid of the first low frequency amplifying valve V_3.

Transformer coupling is used between V_3 and V_4, the primary coil L_5 of the low frequency transformer being in between the plate of V_3 and the positive of the high tension battery and the secondary coil L_6 being joined to the grid of V_4 and to the negative of the low tension battery. A grid biassing battery B_2 is again used, its negative pole being joined to the grid of V_4 *via* the secondary coil L_6.

The plate of V_4 and the plate of V_3 may be joined to the same positive of the high tension battery which in this case may be of the order 120 volts. The plate circuit of V_4, of course, contains the loud speaker **LS.**

Although originally built and used for "ordinary" wireless, we have used this set with slight modifications for television with good results. But see later.

As already indicated, wireless receivers both for ordinary broadcasting and television can be "run off the electric light mains," thus dispensing with both high tension and low tension batteries. If the house supply be alternating current it must, of course, be converted to direct current for the plate supply to the valves, *i.e.* we must have direct current for the high tension supply. To do this we use a transformer, and a rectifier, and in addition to these two some form of smoothing device, the whole being referred to as a **battery eliminator.**

We want you here to understand the method of using the A.C. mains, so will take a diagram as simple as possible: further L.F. stages can soon be added for television purposes.

To illustrate a modern receiver using the A.C. mains, we will take a three-valve set as shown in Fig. 124. All the valves are triodes, and consist of a high frequency amplifier V_1 followed by a detector V_2 and a low frequency amplifier V_3. Transformer coupling is used between V_1 and V_2 and between V_2 and V_3.

The aerial tuning consists of the usual plug-in coil L_1 and variable condenser C_1, the latter being ·0005 microfarad capacity.

The high frequency transformer coupling V_1 and V_2 is the Lewcos high frequency transformer (Art. 6) numbered in the usual way (see Fig. 124). The centre tap, No. 4, of the primary goes to the high tension positive (this we will explain presently). One end, No. 5, of the primary goes to the plate of V_1 and the other end, No. 3, goes to the neutralising condenser C_5 and thence to the grid of the high frequency valve. The secondary coil of the transformer has the usual tuning (variable) condenser C_3 of capacity ·0005 microfarad across it: one end, No. 1, goes to the grid of the detector V_2: the other end, No. 2, goes to a terminal of the grid battery. The coil between 2 and 6 is the reaction coil: it goes *via* the reaction condenser **RC** (·0001 microfarad) to the plate of the detector.

The low frequency transformer coupling the detector V_2 to the low frequency amplifier V_3 is the usual type. The choke coil between the plate of V_2 and the primary **P** smoothes matters. The other end of **P** goes to high tension positive as usual.

Instead of putting the loud speaker direct into the lead from the plate of V_3 to the positive high tension, as is usual, a choke and condenser C_4 (2 microfarad) are arranged as shown, and the loud speaker inserted at **LS**, connections being as indicated. This has certain advantages over the usual method, but we need not worry you about these.

It will be noted that we are using anode bend rectification with the detector valve V_2 (not grid leak), and the connection on the grid battery from No. 2 of the high frequency transformer must be such as will give the required anode bend bias.

We come now to the battery eliminator on the right of Fig. 124. The power transformer on the right has a primary

will be clear that resistance-capacity coupling suggests itself and this coupling has proved successful in practice. We will deal with the question of "negative pictures" presently: at the moment we will merely say that *an anode bend detector with three stages of resistance-capacity coupled amplifiers, or a grid leak detector with four, will be quite all right.*

Just as the loud speaker is placed in the circuit joining the plate of the last valve of an ordinary wireless receiver to the high tension positive, so the neon lamp is placed in the circuit from the connected plates of the parallel valves to the high tension positive (Fig. 127). Another method of joining up the neon is shown in Fig. 125, where L is a choke coil. The neon, as we stated in Chapter III., has to be supplied with a certain voltage before it will "work"—the *striking voltage* as we called it—and the effect of the arrangement of Fig. 125 is that the neon gets this whilst the amplifier voltage can be reduced. Yet another method of connecting the neon is shown in Fig. 126, chokes again being used.

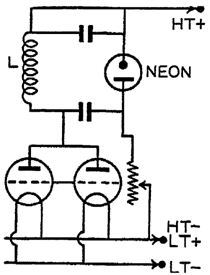


Fig. 125.

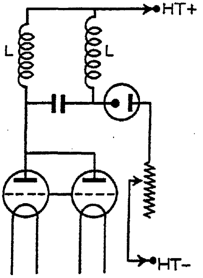


Fig. 126.

In addition to the neon in the output circuit of the last valves we require connections to the two coils on the synchronising mechanism attached to the motor, for you will remember we said in Chapter V. that the synchronising impulses which pass through these two coils, keeping the sending and

receiving motors in step and the picture steady, were part of the picture currents. These coils may be connected in series with the neon, in which case a condenser of about ·1 microfarad is joined across the coils, *i.e.* in parallel with them. Another device is to use a separate valve for the synchronising coils over and above the two valves of the last stage which feed the neon. This enables one to vary the supply to the coils and thus control their "holding power" on the rotating toothed wheel without interfering with the neon current and therefore with the variations in the neon glow which give the picture. The connections for this arrangement are given in Fig. 127, and will be dealt with presently.

We can now consider the lay-out of the complete wireless receiver, and in order that you may concentrate your attention on the low frequency amplifying part we will first assume that no high frequency amplifying valve is employed in the set. As we have said excellent results can be obtained without the high frequency amplification. The circuit is shown in Fig. 127.

The actual high tension supply and the necessary grid bias depend on the type of valve, and are given by the makers. This also regulates the values most suited for certain resistances and capacities used in the receiver: the values given are general values suitable in most cases with good class valves of the LS 5 or DFA or DO types.

Any of the usual aerial tuning devices may be employed. In the arrangement shown we are using an X coil with the usual tuning condenser C_1. It is advisable to use a potentiometer P between the low tension positive and negative to regulate the potential bias on the grid of the detector valve V_1, thus securing the correct potential of the grid for anode bend rectification. The resistance of P may be of the order 300–500 ohms.

Resistance-capacity coupling is used between the detector valve and the first low frequency amplifying valve V_2 in Fig. 127. The resistance R_1 is about 40,000 ohms, and the condenser C_2 has a capacity of ·1 microfarad. It will be noted that a high frequency choke is joined in between the plate of V_1 and the coupling resistance R_1 as was done with the detector valve V_2 of Fig. 123, and that the condenser joined from the bottom

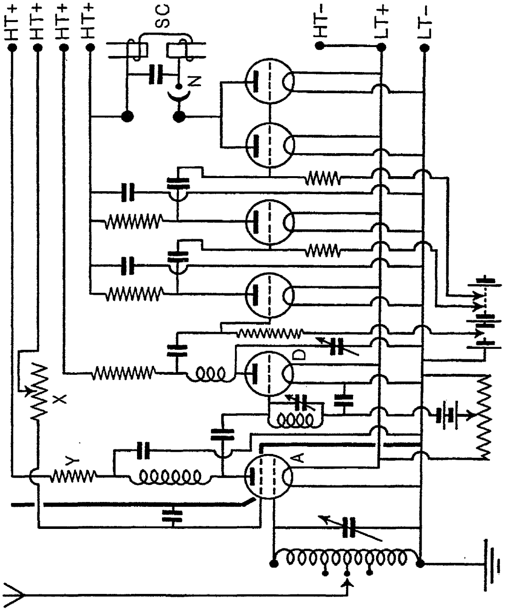


Fig. 128.

ing it in the circuit of Fig. 128. Try both and compare results in your own case. With this coupling it is desirable to use a second tuned circuit in the grid of the detector. For further information on this arrangement the section on "Parallel Feeds" in *First Course in Wireless* should be consulted.

In this circuit the neon and synchronising coils are in series: a separate valve may, of course, be used for the synchronising coils, as in Fig. 127, and any of the methods of feeding the neon previously dealt with may be employed.

We cannot too strongly recommend you, at this stage, to become a regular reader of that excellent little journal *Television*, which is issued monthly. It will keep you thoroughly in touch with the latest developments in the subject, and provide you with constructional and other details which you will find of the utmost value.

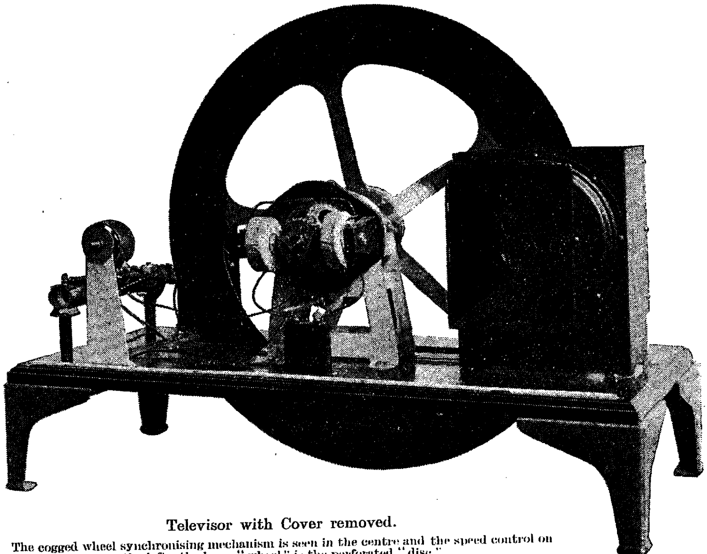
A final word may now be said on the question of positive and negative pictures in television (see pages 110 and 155). As already explained, when the light scattered from the part of the object being televised is "big" the current given by the photo-electric cell is "big," and when the light is "small" the current is "small," and further, when the current through the neon is increased the glow is increased, and when the current is decreased the glow is decreased.

Now when anode bend rectification is used for a detector valve the mean plate current increases when the signals are passing, but when grid leak rectification is used the mean plate current decreases. This has been explained in Chapter VI. Clearly, then, if you and your friend are each provided with a receiver and televisor, the receivers being exactly alike, save that one uses anode bend and the other grid leak rectification, there will be a difference in the resulting pictures. One picture will be "bright" where the other is "dark," *i.e.* one will be correct and the other will be wrong—they will differ just in the same way that a photograph and its negative differ.

Again, if you have a grid leak detector followed by two stages of resistance-capacity coupled amplifying valves the picture will be all right, if there are three stages it will be wrong, if four stages it will be all right. If the detector is

anode-bend three stages of resistance-capacity coupling wil be all right. If you have two stages of transformer couplec low frequency amplifiers after your detector and the picture is all right, and if you then change the first stage to resistance capacity coupling the picture will be wrong.

Should a negative picture be obtained when you start to receive, the fault therefore lies with the wireless receiver, but it is easily corrected. If you are using grid-leak rectification you could change to anode-bend or *vice versa*, and this would correct matters. If you are using resistance-capacity coupling for your low frequency amplifiers then matters will be corrected if you either put on an additional stage of resistance-capacity coupling or take off one of them. If you are using transformer coupling in any stage of your low frequency amplification then if you reverse the connections to the primary of the transformer *or* reverse the connections to the secondary (but do not reverse both), matters will be put right.



Televisor with Cover removed.

The cogged wheel synchronising mechanism is seen in the centre and the speed control on the left: the large "wheel" is the perforated "disc."

CHAPTER VIII.

TELE-CINEMATOGRAPHY. TELE-TALKIES. TELEVISION IN THE THEATRE. TELE-PHOTOGRAPHY.

1. Televising a Silent Film—Tele-Cinematography.—The televising of a film is done almost in the same way as the televising of a living person—in many respects it is simpler—and you should have no difficulty in understanding the method from what you have learned in the preceding pages.

The ordinary film, as you know, consists of a number of pictures printed vertically under each other on a long transparent film, each picture representing a motion just a little after the one above it. With this understanding, the essentials of the method of televising the film will be gathered from Fig. 129 (*a*), which shows the arrangement at the sending end.

In the figure **L** is a powerful light and **A** a lens which concentrates the light on to the film **F**. This film is, in the ordinary way which is adopted with films at the cinema theatre, caused to move upwards through the projector gate **Z**, as it is called. The lens **B** is so placed that it forms a real image of the picture on the revolving scanning disc **D**, provided with the usual 30 holes, whilst *a* and *b* represent again the adjustable plates of Fig. 82, so arranged that only one hole scans the picture image at a time. **P** is the photo-electric cell.

Now in ordinary film shows at the theatre a mechanical arrangement brings the first picture into the path of the light beams from the lamp, and the picture is projected on to the screen. Then the mechanism shuts off the light whilst the next picture is jerked forward into position, then the light comes into action again and the second picture is projected on to the screen, and so on. This is repeated at the rate of about 16 pictures per second for silent films (about 22 for talking films), so that by persistence of vision the audience sees on the screen not a jerky movement of separate pictures but a continuous motion of the people portrayed.

Returning now to the televising of the film (Fig. 129) it is clear that as we have a moving film and a moving disc, "timing" must be carefully attended to, otherwise we may have a hole still scanning the image area during the change over jerk from one picture to the next. If the movement of **F** is so adjusted, however, that one revolution of the disc takes place exactly during one exposure of the picture matters will be all right.

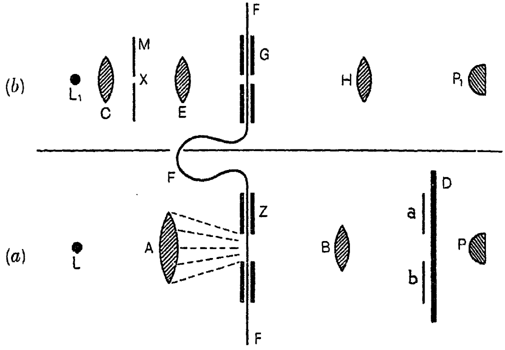


Fig. 129.

Now that talking films with 22 pictures per second are popular the jerky type of mechanism referred to is scarcely suitable for television: it is difficult to "fit in" with the 12·5 pictures per second of the rotating disc. Hence another projector mechanism has been employed, by which the film moves continually, a system of mirrors and lenses being employed to make the pictures glide into each other, so preventing optical defects. These are details, however, which do not concern us.

The disc **D**, as indicated, moves at the usual 750 revolutions per minute, and all that has been said in previous chapters applies here. The holes of the disc "scan" the image at **D**

of the picture in the usual way, the varying light *passing through* the different parts (not *scattered back* as in televising a person) falls on the photo-electric cell **P** which therefore gives a corresponding varying current, which again is caused to modulate a carrier wave, and so on. The "pictures" are received by the wireless set and televisor in the usual way.

2. Televising a Talking Film—Tele-Talkies.—The talking film, as you know, consists of a number of pictures just as in the ordinary film, but in addition there is, down the right-hand edge of the film, a series of lines of varying density which constitutes the sound record, *i.e.* the speech, etc., of the persons in the corresponding picture. Fig. 129 (*b*) will show how this part of the film is dealt with at the sending end.

In the figure L_1 is the source of light, and **C** a lens which concentrates the light on to a narrow slot at **X** in the mask **M**. The lens **E** is so placed that it focuses an image of the slot on the sound record on the edge of the film which is passing upwards through **G**. The light which passes through the sound record meets the lens **H** by which it is spread evenly over the cathode of the photo-electric cell P_1.

Clearly a varying amount of light depending on the varying density of the sound record, and therefore upon the words originally spoken, falls upon P_1 which, in consequence, gives a corresponding varying current. This varying current after being amplified is caused to modulate a carrier wave, and so on. At the receiving end the words are reproduced by a loud speaker or telephones joined to a wireless set in the usual way.

In the figure it will be noted that the film passes first through the picture reproducing apparatus and then through the sound reproducing apparatus. In the tele-talkie film, therefore, the sound record corresponding to a particular picture must not be opposite that picture, but so far *ahead of it* so that sound and corresponding picture will be reproduced together. It is usual to have the sound record 19 pictures in front of the picture to which the sound belongs.

3. Television in the Theatre.—So far we have dealt with that phase of television with which you are mainly interested, *i.e.* reception in your own homes by means of your wireless

receivers, loud speakers, telephones, and televisors, and this applies whether the transmission be from living persons or from films. Just a few words may now be said, however, on the question of *reception* by large audiences in, say, the theatre, and in this, of course, only the " vision " reception need be referred to—the reception of the " sound " by suitable wireless receivers and loud speakers can readily be accomplished and need not be considered.

It will be clear from what you have read in Chapter II. that the picture as received in your televisor can be fairly magnified by means of lenses, and if it were possible to have sufficiently strong illumination, an enlarged image might be obtained on a screen. But herein many practical difficulties arise, with which we need not trouble you.

The problem has, however, recently been solved by Mr. Baird, and not only television proper—the images of living persons—but a talking film has been displayed on a screen on the stage of a London theatre as part of the regular programme.

The screen consists of a large sheet of ground glass fitted behind with 2,100 compartments, in each of which is a small electric lamp. Behind the screen also is a large commutator (as it is called) with 2,100 metal segments, each lamp being joined to one segment. A metal selector brush makes contact with the segments, and as it revolves it makes contact with each segment in turn, thus communicating with each lamp in turn, and if a current is passing at any particular moment that particular lamp will light up. The selector runs at 750 revolutions per minute (the same speed as that of the scanning disc at the sending end), and in one revolution it " scans " the whole of the lamps of the screen.

The object to be televised is scanned in the usual way at the sending end. When the signals arrive at the theatre they are amplified in the usual way, and passed to the screen so that each lamp lights up when the selector brings it into circuit, and the intensity of its illumination depends on the current passing at that instant. Thus the varying illumination of the lamps builds up an image of the object at the sending end. The screen with its lamps and commutator therefore correspond to the neon and scanning disc of the televisor. Syn-

chronism between the sending and receiving apparatus is obtained in the way we have previously described.

4. Miscellaneous.—Apart from what we might call television proper and the televising of silent and talking films, dealt with in preceding pages, Mr. Baird is engaged on numerous applications and modifications, all of which are alike interesting and important.

In television, as you have seen, the person or object is scanned by a spot-light from a powerful lamp. Mr. Baird has also used for this purpose the "dark" waves longer than the red—the infra-red rays as they are called—so that it is possible for you to see a person sitting at a distance in total darkness: the use of this in seeing objects, say, at sea in a dense fog is apparent. In yet another application ordinary daylight has been utilised.

Mr. Baird has also succeeded with colour television, fruit, flowers, etc., in their colours being successfully televised. Red, blue, and green are what we call the three primary colours, and all other colours can be built up by suitably overlapping these. Hence in colour television Mr. Baird uses discs with three sets of holes, the holes being covered with red, blue, and green filters respectively, *i.e.* filters which allow these particular rays to pass. He also uses lamps at the sending end, which are particularly rich in red, blue and green rays.

Going back to Chapter III. you will remember we said that in the scanning disc the first and last three holes were rectangular, not square. This has the effect of concentrating the picture details towards the central parts where they are most required. At present the size of the scene televised is somewhat restricted owing to the present broadcasting regulations. Each station, as you know, is given a certain wave-length (and therefore frequency) for its carrier wave, and is told to keep to it with a view of preventing interference with other stations. Now mathematicians can write down for you an equation which represents the carrier wave of any particular station, and then show you that when the wave is modulated the new equation not only represents the original

carrier but two others—known as "sidebands"—one having a bigger frequency and the other a smaller frequency than the carrier, the actual frequencies depending on the frequency of the modulation.

Each station must therefore not only have a fixed carrier wave-length (and frequency), but a certain sideband allowance must be given above and below the station frequency, and at present the total allowance is 9 kilocycles frequency, *i.e.* 9,000 cycles. Now this sideband allowance is hardly sufficient for the modulation frequencies if large scenes are to be televised in detail. When this sideband obstacle is surmounted there will be little difficulty in having large scenes, and any type of film broadcast and received.

Incidentally we do *not* wish you to conclude from the above that immediately the carrier wave is modulated by, say, a musical note or the light scattered from the tip of a nose, three waves are passed out *through the aether*—the carrier and two sidebands. There is a great deal of dispute just now on this point, and the matter is not yet settled—if it ever will be. We are inclined to favour the idea that the carrier wave is merely modified in such a way that its "swings" or "strength variations" as we called them—more scientifically its "amplitudes"—are altered, and there is a limit to the amount of amplitude alteration we are allowed to make. However, it is a dispute about which you need not worry.

Most countries can claim workers in the field of television. Jenkins in America originally used two wheels with prism edges, the slope or angle of the prism edges varying all round the circumference. When light falls on the wheel the refraction varies with the varying prismatic angle. One wheel, when rotating, causes the refracted beams to move vertically up and down, the other causes them to move horizontally right and left. The action of the two is to cause a rapid movement over each portion of the picture. At the receiving end the varying light from the receiving lamp (known as the *Moore lamp*) is made to move over a screen by a similar arrangement to that used at the sending end and by persistence of vision the image is built up. Jenkins, however, is now using a spiral-holed disc.

Alexanderson uses at the receiving end a drum fitted with small mirrors on its rim, the mirrors being fixed at different angles. When the drum rotates the varying light from the receiving lamp is reflected by each mirror on to a certain portion of the screen and in this way, by persistence of vision, the image is built up on the screen.

Zworykin scans the object at the sending end horizontally, using for this purpose a vibrating mirror which deflects the light from one side to the other. At the receiving end he uses a **cathode ray tube** as it is called.

We have referred to the question of passing an electric discharge through a tube containing gas at a low gas pressure in dealing with the Neon lamp. When the gas pressure is fairly low the discharge consists of a luminous column—known as the *positive column*—stretching from the anode almost to the cathode. At lower gas pressures the column breaks up into bright shells and dark patches: there is a glow on the cathode, and the dark space next to it is called the *Faraday Dark Space.* When the pressure is further reduced the glow moves away from the cathode and another dark space appears next the cathode called the *Crookes dark Space.* Finally this dark space extends until it fills practically the whole tube and the glass becomes phosphoresecent (yellowish green). The cathode is giving out electrons known as *kathode rays* and the phosphorescence of the glass is due to its bombardment by the rays. If the rays fall on a suitable anode at this stage the anode gives out aether pulses or waves known as X-rays.

Now Zworykin uses a special kind of cathode ray tube (a "kinescope") for his receiving apparatus. The pencil of electrons from the cathode bombards a screen of fluorescent material. This pencil is caused to follow the movements of the scanning light at the transmitter, its intensity depends on the electric impulses received from the sending end, and its movement is so rapid over the screen that by persistence of vision the image is built up.

Amongst other workers in television you will come across the names of Mihaly, Bolin, Holwick, Karolus, Ritcheonloff, Whitter, Von Bronk, and others.

The illustration on the cover of this book is from the first Television Play—" The Man with the Flower in his Mouth " —broadcast by the B.B.C., and is reproduced by permission of the Corporation.

5. **Tele-Photography.**—Tele-photography—the transmission of photographs by wire and wireless—is now used by many of the leading newspapers, and as it is a related subject to television a brief reference may be made to it. Three systems are mainly in use, viz. the " Siemens-Karolus-Telefunken," the " Belin," and the " Bell." The first is used for the service arranged by the Post Office between Great Britain and Germany and Denmark, whilst the Belin is used largely in France, and the Bell in America. The Bell system is also used by the *Daily Express* between London, Manchester, and Glasgow, and we will therefore take this system in illustration.

At the sending end the photograph, prepared in the form of a transparency, is mounted on a cylinder which, while rotating, is, by a screw mechanism, moved slowly along in the direction of its axis. A light-spot, which has the same width as the thread of the screw is focussed on the photographic transparency, and as a result of the two movements referred to, the whole picture is scanned in the form of fine, close, parallel strips. Clearly the amount of light transmitted through the picture (or in some systems the amount reflected from it) at any moment will depend on the density of the part of the picture being scanned at that moment. This varying light falls on the kathode of a photo-electric cell and a varying current is produced which after amplification is passed to line or caused to modulate a carrier wave in the usual way.

At the receiving end the varying currents are amplified and then passed into what is called a " light valve " (don't confuse this with the thermionic " valve " already dealt with). The light valve merely consists of a metal ribbon strung in a magnetic field due to a large " field coil." Light from a lamp passes through a hole in the field coil and falls on the ribbon. By means of two movable jaws the size of this hole is so adjusted that when the ribbon is stationary it completely covers the opening so that no light can pass through to the other side.

Now when the incoming varying picture currents pass through, the ribbon vibrates under the alternate polarities as you will understand from what we said in Chapter III., and in so doing it no longer blocks up the opening—some light passes through. The amount passing through varies with the vibration of the ribbon and therefore varies with the varying current received. In other words we get a light passing through which varies in proportion to the current from the photo-electric cell at the sending end and therefore in proportion to the light through the photograph being transmitted. The varying light from the light valve is finally focussed on to a photographic film mounted on a cylinder which is rotating and advancing in synchronism with the photograph and cylinder at the sending end. Thus the photograph is reproduced.

In conclusion we strongly advise you to follow up your reading of this little book by a careful study of *Television To-day and To-morrow,* by Sydney A. Moseley and H. J. Barton Chapple, B.Sc., A.M.I.E.E. This is an excellent and standard work in which the history of the subject, its present details, and its future are fully dealt with.

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